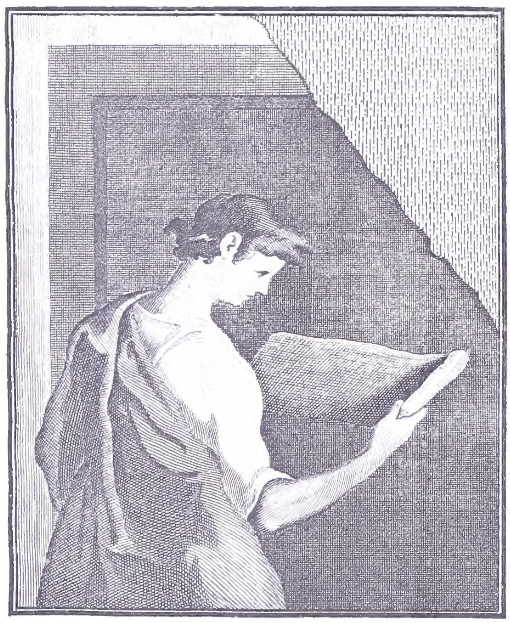

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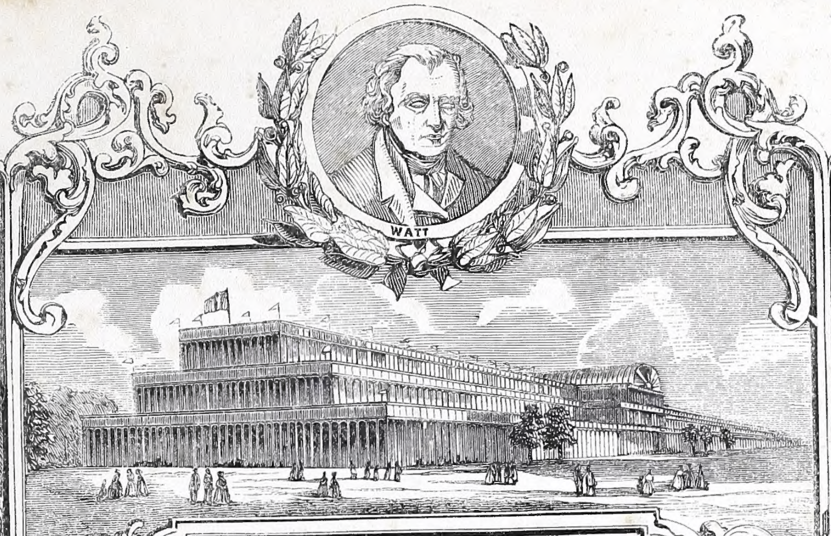

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AND

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THE

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OF

ART, SCIENCE, MECHANICS, AND ENGINEERING.

HISTORY OF THE PHYSICAL SCIENCES.

INTRODUCTORY ESSAY.

ILLUSTRATING THE PRACTICAL BENEFITS CONFERRED BY THEORETICAL SCIENCE.

Although this subject has been treated of by several writers of eminence, their works are, for the most part, too bulky and expensive for the majority of the public. We shall, therefore, need no apology on presenting our readers with a brief, but we trust accurate and impartial, view of the rise, progress, and present condition of Physical Science, giving especial attention to a feature too often overlooked by former authors—its influence upon the outward and inward condition of mankind, and upon the development of society. We shall thus, perhaps, learn the deep importance of a subject too commonly overlooked, not merely by the world at large, but even by professed philosophers, and whilst we gain a key to many of the riddles of the past, we may gather valuable and significant indications as to the future progress of our race. Our readers will doubtless grant that all the outward facts and events of the world, in as far as of human origin—all those substantial realities in which utilitarians and common-sense heroes so much delight, spring ultimately from ideas. Whatever is performed or aimed at by individuals or communities, must have been devised—conceived, no matter how indistinctly—in the mind of the actors themselves, or of some other men, before it can seek outward embodiment. The deed springs from the thought, as the plant from the seed. Practice is but theory condensed, so to speak, and fallen to the earth; whether we be able to embody our theories in words or not, is exceedingly unimportant. The peasant eats his potato, a solid fact enough; could he have done so but for the ideas, the theory of Columbus? The man of business receives intelligence by the electric telegraph, and thereby achieves solid profit; what is this but Oersted's idea become incarnate, after passing through the minds of "lesser gods," such as Wheatstone? The warrior gains battles, and is splendidly rewarded, deservedly or otherwise, but what is he to the inventor of gunpowder? Might we not almost liken him to the apes of whom travellers tell, warming their hands and sometimes burning them (or their neighbours', which serves as well) at a fire lighted by some hunter in the woods? And can we deny, that if a chemist should to-morrow invent a destructive agent ten times more powerful, he might put the empire of the world up to sale? And are laws, institutions, civil government, independent of the intellectual condition of a nation, or uninfluenced by their conceptions of man and nature? A people, in the words of our great Alfred, may be free as their thoughts, but can they be more free? Give the British or the American constitution to a horde of naked savages, or even to those disguised savages east of the Baltic: would it not be to them as worthless as the cargo of skates exported to Brazil by one of your common-sense, untheoretical merchants? The past ages burned harmless men and women—the latter by preference, as one of the privileges of the sex—as sorcerers, whilst the good and sincere of all parties and nations gave, in their ignorance, full sanction to the act. But in the light of science witches and witch-finders have vanished, and we do not find it needful now to slaughter 80,000 human beings annually on false pretences, as in the good old times. If this view, almost self-evident, be correct—if deeds originate as thoughts—and if man's inward development be the necessary measure of his outward dominion over nature, and of the condition of society, the history of speculation is of the utmost importance, and we may assert that the philosophy of history will never be understood until the history of philosophy is more attentively cultivated. For not only, as we shall establish hereafter, is man's rule over nature, his power of subduing the earth, and turning its resources to account, dependent upon the progress of scientific research, but his conceptions of the universe and of his own position therein, the degree of spiritual emancipation which he has attained, flow from the same source. As in the various sciences, all the methods which may be employed in ascertaining truth and detecting error are practically set forth and exemplified, we may safely admit that to the onward progress of science the intellectual education of our

species is mainly due. It is here that the individual and the race must learn to observe, to compare, to generalize, to deduce. Here we learn the extent of our own resources, the invariability of what are commonly called "laws of nature,"* together with many similar lessons not otherwise attainable. It will be no digression if we combat an objection, which may be brought against us at the very outset. "How," it will be asked, "can science be said to develop the intellectual faculties of our species, when such multitudes even in our own country and others, the more civilized regions of the earth, live and die without a knowledge of its truths?" We reply that our remarks relate, in the first place, only to the regions of civilization. To discover and invent is a prerogative limited by Providence to a few tribes of man; of old to the Greek, now to the Celt and the Teuton,† whilst the residue of nations follow in their track. As regards ignorant persons in civilized lands, we may reply with an illustration. Are those places whence the sun's direct rays are excluded, necessarily wrapped in total darkness? Science, like the sun, sheds a diffused light even into those parts of society, which might be likened to cellars and dungeons. The rudest of our population have now, from their contact with the industrial applications of science, grasped ideas which it would have been hard for their fathers to master, and which may be made to serve as starting-points for their further education. Nor are contemplations such as we shall enter upon devoid of a degree of interest, equal perhaps to their utility. True, the records of discovery contain few scenes which would excite "prodigious sensation" at the cheap theatres. They are not garnished with battles and sieges, with fabulous prodigies, nor graced with stories of questionable morality—the *fossil tittle-tattle* of the kings of old, like those volumes which still do sad duty in our schools under the usurped title of "History." They contain nothing to excite the lower passions of our nature, and so may doubtless be condemned by many as dull and "dry." Such men we address not. But is it not a grand, a godlike spectacle to witness man gradually struggling upwards from darkness to light, accepting the universe as the great problem committed to him for solution by his Maker, and bravely bending his energies to the almost superhuman task; to see him, amidst failures and difficulties, still cheered on by the hope of a brighter future, and learning from past defeats the way to victory? Where is the writer who could do full justice to this grand *epos*, man's conquest of nature; or where the reader who can peruse the immortal story without the deepest emotion—without feeling his spiritual being quickened and purified? Nor is the history of philosophy‡ wanting in passages of a truly tragic interest. The thinkers of the past, as the course of our narrative will show, had to contend, not alone with the inbred difficulties of their task—their fellow-men, blinded by suicidal folly, and urged on by false teachers, rose up to frustrate the great work. The lives of too many of the most gifted of our race might be summed up in this brief formula:—He thought, he spoke, he suffered. The case of Galileo is no solitary exception. The pioneers of science, the benefactors of all coming ages, were driven to utter their grand revelations by stealth; to traverse Europe as outlaws and fugitives; to see their toils rewarded with imprisonment, torture, and death. Let us never forget how dearly purchased was the intellectual freedom which we now enjoy.

There is another circumstance which must lend to the history of philosophy a charm the more fascinating from its rarity—the great fact, that it shows us the thinkers of all ages, and of rival nations, labouring in union for one grand object. What people can claim science as its exclusive property? None; however important may have been its labours, they are still but a portion, interwoven with and dependent upon the researches of other nations and other ages. To the discoveries of Newton, the labours of Hipparchus, of Copernicus, of Kepler, of Galileo, were a necessary prelude; and the researches of Laplace, of Euler, of D'Alembert, a scarcely less necessary sequel. Upreared thus by the joint efforts of the thinkers of all times, and of all highly-gifted nations, philosophy is the common heritage of humanity, the shrine where all may meet in brotherly accord. How widely soever we may differ upon other topics, here we have a basis for unity of thought and action—a basis destined, we believe, to be recognized and employed by posterity. Would, especially, that the four modern nations whose intellectual renown has shone most brightly, ever remember this! What nobler bond of union can England, France, Germany, and Italy desire, than the sufferings, the toils, and the glory of their mighty dead? The day must dawn when they shall know it; when they shall join hands, as it were, over the tombs of their sages, and swear to work out henceforth in union the great task committed to them by the providence of God—the promotion of intelligence and civilization, the elevation of our common humanity.

Our subject may, perhaps, be most fitly illustrated by a comparison between ancient and modern society. Next to Christianity, science, with its outward manifestation, industrialism, is the great distinguishing feature of the latter. In all other respects the ancients closely resembled us. In that Sisyphus-toil of the intellect, called metaphysics—a pursuit profitable neither for this life nor for that which is to come—they displayed a wonderful amount of acuteness and profundity. Not a phase of ontological speculation has been put forth in modern times which does not find its model, or at least its germ, in the works of the Greek metaphysicians. It is in fact a painful, yet not the less interesting sight, to behold these men wrestling with problems unsolved and insoluble—straining their splendid faculties to achieve things beyond the reach of man—to penetrate by one great effort to the very fountain-head of all truth—and dying in the full conviction that their great life-task had been accomplished, and a system built up which should for ever satisfy the inquirer. But all those hopes proved delusive. Succeeding generations detected errors and deficiencies in the seemingly perfect structure, and hastened to erect in its stead other fabrics of thought, equally specious and equally short-lived. And thus they went on from age to age; and thus the metaphysicians of modern Europe have trodden in their footsteps, leaving behind them works interesting as monuments of the intellectual condition of past epochs, but otherwise valuable merely as a system of mental gymnastics. How different the progress of science, where, instead of system following system like waves upon the shore, each effacing the

* We prefer, with Lewes, the expression "methods of nature," or rather, of existence.

† Italy, the only exception of note, has received a large influx of Teutonic blood in the North, as of Greek in the South.

‡ We use this term not in the German sense, as equivalent to metaphysics, or ontology, but to denote the harmonized totality of the sciences.

traces of the foregoing, every generation employs the labours of its predecessor as a rock-foundation, upon which to raise higher and higher the grand fabric of positive truth! Changes occur, indeed, in our scientific views, but they are *developments*, not *revolutions*. There is no moving round in a circle; and though new theories approach more closely to absolute truth than those which they replace, the latter often continue useful where a mere approximation is required. Thus, although it is now established that the orbits of the planets are elliptical—and this supposition alone is employed wherever accuracy is needed—still, in giving a popular and introductory view of the main phenomena of the heavens, we may for convenience use the more ancient view, that these orbits are circular. Whilst the philosophers of old thus strove after things beyond mortal reach, the attainable, the beautiful, and useful truths of experimental science, were to a great extent overlooked as valueless. They resembled one running on, over hill and dale, in a vain attempt to catch the rainbow, whilst the soil all around him is flashing with priceless gems which he passes by unheeded. Yet, let us beware how we condemn these men. Above all things let us guard against vain-gloriously dreaming that, had we lived in those days, we should have acted more wisely. Remember the egg of Columbus. It is easy for us, standing upon the pinnacle of a thousand years of victorious research, to gaze down the rugged track along which has gone the march of humanity, and pronounce it simple, natural, easy to find. Let those who harbour such thoughts vindicate themselves, by pointing out the road for a thousand years to come, or even for a few centuries, and we will believe that, had they been contemporaries with Aristotle, they could have done greater things than he. The error of the ancients, and of philosophers in the middle ages, was a stage of development, through which the world must needs pass. Man, placed as in a labyrinth, tried first those paths which seemed to lead more directly to the goal, and not until prolonged trials had convinced him of his error, would he consent to take the apparently circuitous path of induction. It was not until after long bondage in the realms of superstition, long and dreary wanderings in the desert of metaphysics, that our race approached the promised land of positive truth. In literature and poetry the ancients rivalled, or, in the opinion of many not incompetent judges, excelled us. The songs once breathed by the bright waters of the Egean, now echo round the wide world, and waken a love for the beautiful in lands the singers knew not. Now, as of yore, human bosoms still throb to the "tale of Troy divine." It must be granted, as Guizot justly remarks, that in the style, the form of their literary productions, the harmony and correspondence of the various parts, and the artistic finish of the whole, this opinion is far from unfounded. Even their philosophers wrote with an elegance, a refined taste, strikingly contrasted with the loose and slip-shod language in which modern speculation is too often disguised, not clothed, and which tends very much to render it repulsive, not alone to the multitude, but to many educated minds, in which the imaginative, the æsthetic faculty is highly developed.

And if the moderns, as we believe, bring forward ideas infinitely wider, richer, and more varied, it might be asked whether this wealth of material is not in great part due to the intellectual expansion which science brings in its train?

In the fine arts, again, we must yield the palm to antiquity; nay, many have supposed that we can aim at nothing greater than to copy and reproduce the splendid models which Greece has left as an heritage to the world. Yet such men, perhaps, overlook the spirit in a blind adherence to the letter. The Beautiful is one, but it must be revealed to man in ever-varying forms, to suit his stage of inward development. This was the great secret of Greek, as afterwards of Italian art. The sculptor, the painter, embodied ideas which were living in the national mind, and which formed a common ground for him and the public. In the works of Phidias, Greece saw her latent dreams of the godlike all but incarnate. Let our artists go and do likewise. Let them no longer seek for fire upon extinct altars; let them scorn to embroider the skirts of outworn superstitions, or to add spices to the cup of sensuality. Of Venus and Bacchus, of Magdalen and Madonna, ever so beautifully executed, the world is by this time sick. Let them seize upon grander, wider ideas, commensurate to the age, and they may yet, like their predecessors, stand forth as guides and teachers of the nations, and have their names enshrined in the grateful heart of humanity. And not only are we inferior to antiquity in the higher, the creative branches of art; but, in the decoration of our houses, our furniture, earthenware, apparel, how far do we fall short of Greece, Rome, Etruria, Egypt, Assyria! The beautiful tissues, the pigments, the varieties of wood and stone at our disposal, serve only for our condemnation. What exquisite ornaments did they execute from the resources of a comparatively narrow region, whilst we, with the riches of the world at command, perpetrate abortions, often most frightful where most elaborate and expensive!

What then remains but to admit, that, except as far as the Christian religion is concerned, our sole distinction from antiquity is, inwardly science, outwardly industrialism? a distinction amply sufficient to show that the world has advanced, and is still advancing. Not, indeed, that physical science was entirely wanting among the ancients. It existed in embryo: some of its departments were already definitely constituted. The labours of Aristotle, Archimedes, and Hipparchus, are too valuable to be forgotten. But it had as yet little or no influence, it filled no place in their social economy. Practical applications of any truth which the philosopher might discover, were rather shunned than sought, being regarded as a desecration. To such an extent was this principle carried, that many eminent sages of old are said to have had two distinct doctrines; an esoteric, or inward, for a select few, and an exoteric, or outward, for the public at large—the latter purposely expressed in such a manner as to conceal instead of revealing the ideas therein contained.*

"Odi profanum vulgus et arceo," was the motto of the philosopher, as well as of the poet. But even where knowledge was not purposely concealed, still less did its diffusion form an object with the learned. Had, therefore, the attainments of individual philosophers been even greater than was actually the case, we should still be warranted in saying that science formed no characteristic

* Such was the practice of Aristotle, if we are to believe his letter addressed to his former pupil, Alexander, who had blamed him for the publication of his works. Yet we rather conclude that in this case the philosopher merely availed himself of a pretext which the custom of the age rendered plausible, in order to soothe the anger of his royal disciple. That a teacher should discourse in a different manner to a select circle of advanced pupils, and to an ignorant and promiscuous multitude, is not to be condemned. The former class will require and appreciate what the latter would reject. But woe to the man who delivers contradictory doctrines, and wilfully deludes his fellow-creatures.

feature of antiquity. The useful arts, indeed, existed, but in a state comparatively rude and imperfect, and, above all, they were viewed with contempt. The artisans of Greece and Rome were for the most part slaves, or freemen of the lowest classes. No one could rise to wealth or influence by manufacturing industry. Their operations were upon a very limited scale, machinery was comparatively unknown, and manual labour was their chief source of power. They worked by rote, as the bee or the beaver, and whatever improvements were effected were the fruit of accident, and probably too often perished with their first possessor. Wherever science is mystical, as in Egypt, or exclusive, as in Greece and Rome, there art must be empirical, blind, restricted to the old paths.

Hence the comparatively stationary character of ancient society. Look at ancient Rome—new provinces might be added to the empire by conquest—wealth might be increased by the booty of war, or the tribute of the vanquished—luxury might advance with corresponding steps, but otherwise all remains the same. We find none of those great inventions and discoveries which, in modern times, mark out epochs of change, and modify both the physical and moral condition of the world. Gunpowder, the compass, printing, the steam-engine, vaccination, railways, the electric telegraph; each of these words marks an onward step such as Rome never knew—a step in which, consciously or not, the whole world is implicated. This is the salvation of modern society; we feel ourselves ascending, advancing. Rome had no such stimulus, no hope in the future, and therefore gave herself up to vice and luxury, just as a desperate man sometimes attempts to drown the remembrance of his misfortunes in intoxication.

But when we hear it stated that science and industrialism characterize the modern world, we may not be at once aware of the vast meaning couched in these few words. What do we owe to science? Far more than we usually suppose, and that not merely in things outward. The case stands thus: we are placed in a universe where—

> "From heaven's star-fretted dome,
> To the dull weed some sea-worm battens on;"

everything exists and happens in accordance with laws (modes of being) invariable and resistless. For proof of this, we refer you not so much to the various sciences, as to the experience of daily life. Should the sun not rise at its accustomed hour—should opaque bodies not cast a shadow—should a piece of dry timber, laid upon the fire, refuse to burn, or a ball of lead, cast into water, float upon the surface—wonder and alarm would nigh make you doubt your own eyesight. Does any unusual phenomenon* occur, even of a kind which threatens no immediate danger—a meteor, an aurora, a swarm of uncommon insects, an animal or vegetable monstrosity—the veriest clown of ancient Bœotia, or modern Pomerania, gazes upon it bewildered. So constant is the "order of nature,"† that from the past—save in matters of a highly complicated order—we feel warranted in predicting the future. Is it not, then, of the highest importance to us to know these laws, this order of nature, that we may adapt ourselves to its action? To this the whole practice of men in their ordinary dealings gives one affirmative reply. The navigator seeks to ascertain the winds and currents in the seas he is about to cross, that he may turn these powerful agents to his advantage, instead of idly striving against them. Should one wrap himself in furs in summer, and discard his warm garments at the fall of the leaf—should he sleep by day, and go out to view the country at midnight—he would be proclaimed at once a madman; but whoever adapts himself to the changes of the seasons, and yet doubts the utility of science, commits the folly of denying a sum total, and yet admitting all the items of which it is composed. Unless we observe the laws of nature, we must suffer, and we cannot observe them unless we investigate.

What says the father of modern philosophy? "Man, the servant and interpreter of nature, can act and understand only as far as he has, either in act or thought, observed the order of nature; more he can neither know nor perform." And again—"for nature is only conquered by obeying her." Now it is by science, and by science alone, that we can observe the order of nature; that we can comprehend and "obey her laws," thus rising from boundless obedience to boundless empire. And here, did space permit, we might recount the benefits which, in "numbers numberless," science and its applications have conferred upon us, and which have raised us so high above our forefathers in power, in security, in comfort. Look, for instance, at the artificial lights. The ancients and the moderns, till a recent period, had no resource but lamps and candles, which, however multiplied, proved at once a miserable and a costly substitute for daylight. The streets of towns were involved after sunset in darkness, broken only by the feeble gleams from a few oil lamps, which, on account of the expense, were extinguished whenever nominal moonlight afforded a pretext. Hence person and property were alike insecure, and full encouragement was given to every kind of crime and immorality. But now the discovery of coal-gas—a result of the advance of chemistry—enables us to illuminate our dwellings, public halls, and churches, with a flood of radiance, compared with which the banqueting halls of the Cæsars would look dim and dark, and this too at a comparatively trifling expense. Our streets are lighted in such a manner that public security is as complete by night as by day, whilst any person meditating an outrage feels that he is constantly liable to be seen and recognized. Even where the introduction of gas is not practicable, as in rural villages and solitary dwellings, our knowledge of the laws of combustion, and of the nature of oily and fatty bodies, has enabled us to prepare lamps and candles at once more effectual and cheaper than in times past. In no respect have the modern improvements in artificial lighting been more important than in the arrangement of lighthouses. Of old, the only method for warning the mariner against dangerous coasts, was to maintain a number of dull oil lamps, or to kindle a huge bonfire, which, being necessarily in the open air, was likely to be extinguished in stormy nights, when most required. Now, lamps of the most intense brilliance are placed in the focus of reflectors, so contrived as to concentrate and utilize every ray of light. It is not easy to calculate the amount of life and property saved from destruction by this single application of optical and chemical science.

* The term "phenomenon" is vulgarly used to signify a remarkable or astonishing occurrence. This is an error. It means simply anything which *appears* to any of our senses, and might be replaced by "appearance" had not the latter come to indicate something false or unreal.

† Under "nature" too many conceive a kind of power or force, distinct from objects, and acting as a sort of vicegerent to the Deity. In this manner, many authors have mystified themselves and their readers not a little. Let us hold fast to the original meaning of the word, and view nature merely as the aggregate of matter, as the "ever growing, springing up" (*nascor, φυω*).

From light we are naturally led to the way of attaining it. Imagine a cold, dark winter's morning, and some unlucky man or woman, with chilled fingers, hammering away with flint and steel for some five or ten minutes before a flame could be procured. Nor was ludicrous discomfort the whole of the evil. Cases might frequently happen in which such a delay in procuring light would have the most serious consequences, as in a sudden attack of illness during the night. But, now the properties of phosphorus, chlorate of potash, &c., are known, we have the means of instantly procuring light at command. And yet men were found absurd enough to regret the invention of lucifer matches, because they were occasionally used by incendiaries; as if, forsooth, the latter, if so disposed, could not have found other means of executing their purpose. We make bold to say, that the time saved by the nation, since lucifers took the place of old tinder-box, far outweighs the value of all property destroyed by the aid of these ingenious contrivances.

In warming our apartments, advances almost equally great have been effected since the laws of heat and of combustion were more accurately known.* The appliances of old were stoves, in which the outer surface often became red-hot—whence danger and nuisance; open braziers containing charcoal, and filling the air with deadly fumes; and huge fire-grates, placed at a considerable height above the floor, and so constructed that, for every ten parts of heat generated, nine were wasted. Now we have changed all this. Modern stoves impart heat by a large metallic or earthenware surface at a low temperature, thus avoiding the hazard of fire and the generation of noxious fumes. The gas stove,† especially, affords a cheap, cleanly method of maintaining a uniform temperature without constant attendance, and is therefore invaluable in the sleeping apartments of invalids. Knowing that heated air ascends, and that, if the floor of a room be sufficiently warm, its upper regions will, so to speak, take care of themselves; we place our fire-grates low, so as to radiate the heat upon the floor and upon that part of the body most in need thereof—the feet; whilst metal reflectors cast forwards into the room that portion of heat which was, on the old plan, absorbed into the brickwork and wasted. In large public buildings, again, the use of steam, hot air, and hot water, conducted under the floors in metal pipes, is a source of great pecuniary saving, and has the advantage of maintaining the whole of a building at one uniform temperature, without the annoyance of smoke and dust—an exemption of high importance in museums, public libraries, and galleries of art.

Systematic ventilation was in former times unknown, nor would it have been practicable until the nature of the atmosphere and of the respiratory process had been ascertained. In southern Europe, indeed, the out-door habits of the population render such improvements less imperative; and in the middle ages, the rude construction of all dwellings, from the knightly hall to the vassal's den, afforded ingress and egress to all the winds of heaven. But during the two last centuries, the more closely a room approached the condition of a hermetically sealed receiver, the greater satisfaction was felt. Now we are enabled at once to maintain the air in our habitations in a state of needful purity, and to guard against the ill effects produced by the entrance of chilling draughts.

The outward material benefits derived from the steam-engine, especially when applied to locomotion by land and water, are almost too threadbare a subject for notice. We are all familiar with the stimulus it has given to trade and manufactures, and with the vast amount of time and labour saved through its instrumentality. Yet we sometimes forget that this mighty invention of modern times has produced moral and social results no less important, if less manifest at the first glance, than the increase of man's outward power and resources which has followed in its track. To these we shall allude below.

But it is not the steam-engine only which has given us means of navigation unknown to the ancients, enabling us to effect, in a few weeks, voyages which took them a year to accomplish.

The compass, the chronometer, the telescope, were all needed. And what an amount of research in optics, mechanics, magnetism, had to elapse before these instruments were all brought to their modern state of perfection! Had one of our "practical men" seen Kepler studying the orbits of the planets, or Newton, immersed in profound thought, striving to demonstrate his great theory of attraction, he would perhaps have bidden the philosopher get up and do "something useful." But now we can trace the result.

No less striking have been the services of science in the detection of crime. In former times, if we may judge from the number of eminent personages whose death had in it some mysterious feature, the offence of poisoning was no less frequent than in our days, whilst there was little prospect of bringing home the charge to the criminal. Now, on the contrary, he has little chance of escape. Traces of blood upon the clothes of a murderer, or upon the blade of a weapon, are detected by chemical and microscopic scrutiny, even after a length of time has gone by, and thus an important link of evidence is often supplied. Have fraudulent erasures and alterations been made in wills, deeds, or other legal documents? The chemist steps in, and not only points out the precise locality and extent of the substitution, but even restores the effaced words. Does a criminal seek to make his escape by flight? The electric telegraph outstrips his speed, and warns the officers of justice of his approach. Railways, instead of aiding a fugitive offender, prove generally a trap from which there is no escape. In some countries, photography has even been called into requisition to preserve an accurate portrait of every convicted criminal, and thus aid in his recognition, should he again be brought before the tribunals.

Look again to the art of medicine. Not but much, very much, remains to be done; physiology, in all its branches, is the problem of the future, as chemistry is of the present. But the sum of lives saved by vaccination alone amounts to millions, even though its usefulness has been much restricted by ignorance, neglect, and bigotry. Aneurism, formerly always fatal, can now generally be remedied, except when seated in deep-lying arteries. Lithotomy, amputations, the extraction of bullets, and other operations, which, in ancient times, frequently cost the life of the patient, and always exposed him to severe and protracted suffering, are now, thanks to the advance of anatomy, performed with comparative ease and safety.

* These remarks apply less to the regions of classic antiquity than to the middle ages and the few last centuries, as, save for culinary purposes, the former made little use of artificial heat.

† Be it understood, *if provided with a flue*. We cannot help warning the reader against all flueless stoves, whatever be the fuel, or however they are be-puffed and recommended. If there is no current of air, the fire must go out; and if there is, the deadly products of combustion must fill the apartment. All attempts to absorb the carbonic acid evolved, by means of quicklime, are practically failures.

Whilst, formerly, it was often needful to administer crude vegetable substances in great bulk, in order to introduce a sufficient amount of some one principle therein contained, thus burdening the system with useless and, perhaps, irritating matter, chemical science enables us to extract from medicinal herbs their active constituents, which are then given in small doses.

We can, however, proceed no further with this enumeration. If any one remains unconvinced, we desire him to look around, and point out, if he can, some good thing which science has neither created, improved, nor rendered more accessible. We do not assert that no such things exist, but we may safely pronounce them very rare. But, plead some in objection, "advance *formal* is not advance *essential;* material improvements do not necessarily imply any moral progress; it is not denied that science, with its applications, may lend life an outward polish, and increase man's comforts, but it leaves him inwardly the same. Amidst all the blaze of science, all the triumphs of intellect, human nature remains unaltered; the same in the steam-carriage of modern England, as in the frail bark canoe of the ancient Briton; in the sculptured halls of Munich, as in the smoky hut of the Samoyede." Such objections we often hear stated, and in very picturesque language. Nor, from a certain point of view, are they entirely without foundation. Still, within the ground we have chosen, we need not fear to meet them. They have, in the first place, the disadvantage of taking for granted the very point at issue. That science cannot benefit society should be proved, not asserted. If they appeal to the past, we would inquire when anything like a fair and full experiment has been made? We protest, further, against this separation of the inward and outward, of man and nature. We proclaim them parts of one system, governed by kindred laws, mutually influenced and influencing. Man's passions, we grant, are, in themselves, beyond our power; we no more pretend to alter them than we do to transmute the elements, or any other of the data which the universe puts within our reach. But the objects on which they feed, the events which call them into play, feel the sway of progress, and this is quite sufficient. The character of man is influenced, in its visible manifestations at least, by the very geological nature of the soil upon which he treads. The more the intellect is emancipated and developed, the less is man disposed to seek his pleasures or the aim of his existence in the regions of sensualism, of animal excitement. Inward, like outward light, is unfavourable to evil. Scarcely a vice but is directly or indirectly countenanced by ignorance. Mental cultivation, though it cannot eradicate bad passions, removes the levers by which they act upon us, and teaches us to give, at all events, a fair hearing to every truth which may cross our path. Let us examine whether science and industrialism have had no moral effects upon society, whether they have merely served to augment our physical comforts. They have had, in the first place, a very prominent share in the abolition of slavery and serfdom in the civilized world. If we look to the origin of slavery, we shall find that conquerors, instead of massacring the prisoners taken in battle, fell upon the notion of sparing their lives, in order to impose upon them work deemed too laborious or degrading for free men. Hence we find that, in antiquity, slaves were employed in grinding corn, in propelling galleys, in carrying burdens, in dragging carriages. But, with the advance of mechanical science, these services were performed, and more advantageously performed, by wind, water, and animal power, skilfully applied. Machinery, in short, superseded the slave, and other motives conspiring, emancipation followed.

To science and industrialism we are also, in a great measure, indebted for the formation of a middle class in society. It will be granted that this class owes almost its very existence to manufactures and trade; and what would they have been but for science? The very rapid increase of this class in social importance, since the discovery of the steam-engine, is a sufficient instance how closely their welfare is bound up with the progress of physical research. Now, what England would be, if inhabited merely by landed proprietors and peasants—what would be her condition, moral, social, political, is a question that scarcely needs asking.

But again, if we look to antiquity, we find foreign conquest and domestic intrigue to be almost the sole direction in which men of action could display their energies. War was, consequently, not, as at present, an extreme measure, embraced with reluctance, a departure from the ordinary course of things. It was the normal condition of ancient states, a prime necessity of their existence, as the sole means of absorbing the activity of the people. And when a nation had extended its conquests to some limit no longer to be crossed, it fell into civil commotions, and into that universal corruption of morals which stains the later ages of the Roman empire. Now, on the other hand, all this energy is safely and usefully directed in another channel. The man of action turns his attention to industry, commerce, the useful arts, colonization. By these he finds he can attain wealth and social consideration. The conquest of nature, not of our fellow-men, is the great daily task of the modern world. Nor has science produced a less beneficial change with the men of theory, of speculation. They no longer move round in a circle, each refuting the labours of his predecessor, but unable to replace them with anything more substantial. Now they perceive open before them an endless field of research, over which they can proceed from triumph to triumph, whilst from their most abstract investigations results abundant practical advantage to the world at large.

The ceaseless verbal disputes of the ancient philosophic schools, the sophistry of their teachers, and the successive rise and fall of contending doctrines, had a most unfavourable effect upon the public mind, and tended not a little to foster that corruption to which we have already alluded. "What is truth?" was asked not by Pilate alone, but by many a Roman as he turned away with a sneer from the assembly where stoic, epicurean, and academician, were urging the claims of their rival doctrines—convinced in his heart that the pursuit of knowledge was fruitless, and all philosophy an idle dream.

One of the most valuable results of science has been the overthrow of superstition. Scarcely can we, in these days, realize to ourselves the fictitious horrors with which our forefathers were tormented. Witches, goblins, and fairies beset their paths; every old house, every churchyard, was haunted by unearthly beings. Storms, blight, sickness, were referred to the malignity of some enchanter, and the most ridiculous methods were used for protection. Nor were these methods merely ridiculous, but often in the highest degree sanguinary. Witchcraft was made an offence punishable with death at the stake, and every

exertion was used to detect those guilty of this imaginary crime. The slightest peculiarity in the dress, habits, or demeanour of a person, especially of females in advanced life, was enough to raise suspicion, and suspicion almost invariably led to condemnation, popular dread of the crime making every one forget to inquire whether the accused were actually criminal. Torture brought on confession, and execution followed, as a matter of course. The number of victims sacrificed to this delusion was prodigious. In Geneva alone five hundred persons suffered death, on this charge, in the year 1515. Nine hundred were put to death by the inquisitor Remigius, in Lorraine. Within the space of a few years, eighty thousand human beings were executed by order of one commissioner, in the district bordering upon the Rhine. Take up the chronicles of any ancient city in England, France, or Germany, and you will find stories of witch-burnings in almost every chapter. Professed witch-finders (such as the celebrated Jenkins, who flourished in the time of Charles II.) traversed the country, and received a reward for every case of sorcery they could detect. Private malice was of course not backward in availing itself of such opportunities. The easiest manner of getting rid of an enemy was to denounce him. In short, upon the most moderate computation, no fewer than a million of our fellow-creatures must, in the space of little more than a century, have fallen victims to ignorance and superstition—a stain upon the annals of mankind, compared with which the "reign of terror" in Paris, the theme of so much vapid declamation, sinks into utter insignificance. As lately as 1720, a woman suffered death for this offence in Scotland. Now these lamentable cruelties were perpetrated in all countries, under all forms of government and religion. Catholic and protestant, royalist and republican, vied with each other in the zeal with which they carried on this deplorable work. To science, therefore, alone we owe our rescue from such crimes and absurdities. Astronomical calculations taught the public to laugh at the notion of old women producing eclipses and altering the orbits of the stars. Disease and blight were traced, not to charms and incantations, but to filth, bad living, and careless agriculture. The permanence and invariability of the order of nature was felt by all cultivated minds. The stories upon which the belief in sorcery had rested, when sifted by men trained in the school of Bacon and Descartes, were found utterly worthless, and at last the penal laws against witchcraft were rescinded, and the avowed, the *official* reign, of superstition was at an end.

Intimately connected with this subject is a consideration to which we need but briefly revert, the education of the public mind through the instrumentality of science. Where else should we obtain a habit of suspending judgment until sufficient evidence has been obtained, freedom from narrow-mindedness and prejudice, and the ability to regard men and things from other points of view, beside the one prevalent in our own age and country? Furthermore, whilst science cheers us on with continued success, and opens up the brightest prospects to our race in the future, she does not fail to remind us, from time to time, of the feebleness of our own resources. Nay, in no other spirit but that of profound humility can nature be successfully investigated. To know and to accept of the limitations of our being, is a great part of wisdom.

And now, let us take an instance of some "mere material, outward" improvement. Has the introduction of railways had no other effect but the promotion of traffic and the increase of wealth? By increasing the ease of communication, by bringing men into more frequent and varied contact, they have proved great moral teachers. They have served to diminish prejudice; to spread truth; to stimulate thought; to fuse classes, occupations, provinces, nations, into one mighty whole; to make mankind more intelligent, more loving, more sympathetic; in a word, to further the great idea of humanity. The writer, when a child, has heard old men tell how, formerly, in the north of England, each village formed a detached and isolated community, whose inmates, by constant intermarriage, had become a kind of clan, and were marked out from their neighbours by some peculiarity of dialect. A passing traveller was always exposed to ridicule, whilst a stranger who came to settle amongst them was the object of annoyance and petty persecution. The man who had been a hundred miles from home, was regarded as an oracle. Now, let us for a moment reflect what dens of narrow-minded prejudice must such villages have been. For it is in little isolated communities, in small islands, that prejudice is most rampant, and ignorance maintains the firmest footing. Take, for instance, a Manx man, or a West Indian, and you will generally find him narrow-minded, obstinately attached to old routine. The Englishman, as a rule, is more prejudiced than the German; whilst the latter, placed in the centre of Europe, and coming in contact, upon different frontiers, with most of its leading nations, is, of all men, the most liberal in his manner of thinking. It is only where intercourse is frequent and varied, where men of different races, views, occupations, interests, are mixed up together, that civilization really advances.* But, to return. What an element of national weakness must have been this subdivision of the people into detached, often hostile groups, linked together by no community of feeling, and scarcely speaking the same language! Surely, then, those improved means of communication which have broken through such local and provincial distinctions, which have made us *one*, and which have so powerfully tended to the creation of public opinion, have not been without moral influence, and have a value other than that of the share-market. Whether such results entered the views of their projectors, is quite foreign to the question. Whatever improves the outward machinery of society, improves also its inward spirit. Whatsoever promotes human comfort, frees some weak mind from the stain of temptation. Whatever lightens or abridges toil, sets free, in proportion, our spiritual being to bask in its native element. Seen in this light, we may well say that utilitarianism itself has an aspect of truth and sacredness.

But some, again, assert that the triumphs of intellect have not, upon the whole, promoted the happiness of the majority; that while they have raised a few to riches, honour, and influence, otherwise unattainable, they have left the condition of the many unimproved, making it appear from contrast the more galling, or even rendering it positively worse. The objection is thus stated in the strongest terms. Yet on this point we might join issue with good confidence. Although, as Hallam has shown, by comparing the present rate of wages and prices of food with those prevalent in the reign of Henry VIII., the margin intervening between the working classes and

* Hence the dark side of emigration. The emigrant may rise to greater wealth than he possessed at home, but he falls back, almost of necessity, in the scale of civilization.

starvation is narrower than it was then, still man has so many necessities besides eating and drinking that the scale turns in favour of the present day. Most of the improvements we have been describing reach the poor as well as the rich. The labourer in sickness may enjoy medical skill which the princes of former days could not command. If compelled to travel in search of employment, his journey may be performed rapidly and cheaply, whilst his forefathers were almost, like shell-fish, restricted to the spot of their birth. The means of education, of gratifying the wants of his spiritual nature, formerly inaccessible, are now thrown open.* In short, we might, probably, demonstrate that every individual in civilized regions has been a gainer by science and its results, few and incomplete as they have yet been.

But, to avoid every appearance of sophistry, we will yield this point. To those who say that science has been the cause of misery to thousands, we will reply—"Granted; but wherefore?" Perhaps the fault lies not in her gifts, but in our manner of using them. The idiot who thrust his legs into his coat sleeve had little comfort in walking. Let us take a parable. An old man of dubious character is dangerously ill. By his bed stands an able and benevolent physician. "You have done me no good," whines the patient; "I feel worse instead of better." "Very sad; but, pray, have you followed my prescriptions?" "Well, no, I did not entirely trust you; the old women about the house thought your medicines were strange; so I took only a part, and flung the rest away." What can the most skilful practitioner do in such a case? And has not society treated the advice of inductive philosophy in a like manner? Where her prescriptions led to wealth they have been frequently, though not always,† followed; where human health, life, happiness, character, the development of individuals and communities, were concerned, they have been deemed strange by the "old women about the house," and flung away as useless. When science bade us reform our sewers, and graveyards, and narrow streets, we found "vested interests" in the way, and turned on the other side for a "little more slumber," till wearied Providence sent the cholera to arouse us. As often as she bids us reform our machinery we fall to work at once, all vested interests notwithstanding. As to the servants of science, no class of men, in this age and country, at least, has been treated with neglect more unmerited and more uniform. We have commanded them, under penalty of starvation, not to *discover*, but merely to *apply*, thus fettering our own progress. And this, I would remark in passing, is the blind, the unholy side of utilitarianism. There may be cases, too, where the partial following of good advice is more dangerous than its total rejection. Heat a glass vessel from one side only, and it will generally break in pieces; apply the heat from all sides, and it remains unhurt. There is neither honour nor security in half measures. Either believe in the intellect, or renounce it altogether, and return as savages to the woods. The great book of nature is not entirely taken up with steam-engines. There are other chapters, to which, ere long, you will be glad to listen. If, then, the benefits of science have failed to reach any part of the community, let us blame our own sluggishness and our own folly.

* Whilst we are bitterly debating on education for the people, it is sad to see how little the people appreciate those means of education which already exist.

† *Enlightened* self-interest is only one degree more abundant than disinterestedness.

Seeing, therefore, what science has done for us, how its progress constitutes our great superiority over the ancient world, the subject upon which we are entering must surely possess deep and general interest. But the history of science is not only a key to the mental development of our race; it not only brings clearly before us the numberless advantages we have reaped from speculative research; there is yet another consideration, of little inferior interest, to which we will briefly advert in passing. The man whose sole aim is to "get himself up" for an examination, or he who is merely collecting recipés, may be content with works which simply indicate the present state of science. But the true philosopher will likewise ask—"How has this state been attained?" He will watch with intense interest the upward struggles of his predecessors, and will thus glean many a significant hint for his own career. It sometimes occurs, also, that in the hurry and confusion of events a train of research has been prematurely abandoned. In studying the history of science, we often thus come upon forsaken workings, which may yet yield precious ore to the persevering investigator.

Having thus, therefore, shown the importance of our subject—that the history of science is, in fact, an index of the development of human nature—we shall proceed in our first chapter to notice the rise and early career of speculative inquiry.

INORGANIC CHEMISTRY.

CHAPTER III.

CHEMICAL APPARATUS AND MANIPULATION.

Manipulation, or the art of rightly conducting the various processes employed in chemical research, is of the first importance to the student. If we remember that experiment is an interrogation of nature, it will at once appear that unless our questions are skilfully put, they will receive a negative or an ambiguous answer. In other words, unless we are perfect masters of the instruments we employ, and the operations we perform, our results will be doubtful or fallacious, and even when correct they will have been obtained at a very superfluous expenditure of time and materials. Perfection in this department involves close and unwearied attention to a number of circumstances apparently trifling, but not the less essential to success. We shall, therefore, briefly review the principal operations of the laboratory, calling the attention of the reader more especially to such precautions as he might otherwise easily overlook.

CLEANSING APPARATUS.

It has been well remarked, that he who is above washing pots and glasses may as well step out of the laboratory at once. Whatever other qualities he may possess, it is no place for him. The student must not think of leaving these matters to others, as he will grant as soon as he has fully comprehended the idea of *chemical purity*. What is dirt? In ordinary language, something offensive to the senses. But to the chemist, everything is dirt except the ingredients with which he is at present engaged. All other substances he must carefully exclude. From this point of view, it becomes evident what scrupulous care is required, not only as to the purity of the bodies employed, but to prevent all foreign matter from adhering to the vessels. No piece of apparatus should be put by dirty; glass rods or stirrers should be kept in a clean place, and the corks or stoppers of bottles, when taken out, should be laid upon a piece of clean glass. Attention should be paid to the state of funnels, spoons, and other instruments used in transferring liquids from one

vessel to another. All dirty glasses should be set aside in one particular place until they can be washed.

In cleansing the interior of apparatus, we use copper wires, about $\frac{1}{6}$ of an inch thick, and 12 to 18 inches long. A set of six or eight should be in readiness, bent into an eye at one end, and with a little tow wrapped round them at the other, which should be roughened with a file. Some should be straight and others bent. A similar set of iron wires of a smaller diameter, serve for cleaning narrow tubes. Some wires should also be kept without tow, in order to scrape off hard adhesive matter. A few sticks of light wood, flat at the end, and about 2 feet in length, are useful in wiping the inside of jars and bottles.

Open glasses may generally be cleansed by rinsing with water. They should then be turned upside down, and left to drain for some hours, and finally dried with very clean cloths, one in each hand. Spots of dirt that adhere obstinately, may be removed by dipping the tow at the end of the copper wire in ashes, and rubbing it on the place.

Grease, resin, turpentine, and similar substances, may be removed by strong sulphuric acid, the vessel being afterwards well rinsed with water.

Tubes are cleaned in the same manner as glasses, the wires serving to remove any dirt that clings to the inside. They are dried by means of long slips of cloth wound upon a stick of proper size.

Flasks and retorts are less easily cleaned, and often require the use of nitric or nitro-hydrochloric acid. They are dried by thrusting a piece of glass tube into the neck, and sucking up the air, the flask being at the same time gently heated, so as to vaporize the water within.

Bottles require much care. The stoppers often become fixed, to prevent which, they should be often examined. If a stopper is found fast, it may be gently struck with a light piece of wood, alternately on opposite sides. A stopper is sometimes extracted by cautiously warming the neck of the bottle over a spirit-lamp, giving it slight blows or shocks as above. A little olive oil, water, or muriatic acid, as the case requires, put round the edge of the stopper, will sometimes remove the obstruction. If all these methods fail, the stopper is wrapped in one or two folds of flannel or soft leather, and then wrenched round with pincers, applying the pressure gradually. In cleansing the inside of bottles, shot should never be used, as it deposits lead upon the glass. Fragments of charcoal are far preferable. Mortars are cleaned by grinding down sharp sand in them, an acid being added if required. A platinum crucible is cleansed by heating it red hot over the gas-lamp, and sprinkling upon it a mixture of equal parts of borax and carbonate of potash. It is then thrown into water, which dissolves away the flux together with the impurities.

WEIGHING.

As it is by the balance alone that exact numerical data can be obtained, the operation of weighing is of the utmost importance. The quantities employed in a chemical experiment should always be determined by weight, not merely guessed. The balance employed for ordinary operation should be capable of turning with half a grain, but, for analytical research, one indicating $\frac{1}{100}$ of a grain is required. These delicate balances are protected from the air by glass cases. The scales should always be lowered upon their supports when any body is either put in or taken out. Powders and fragmentary substances should not be placed at once in the scale pan, but in a light glass capsule, or a piece of smooth glazed paper, exactly counterpoised. It is well to appropriate one scale exclusively to weights, and the other to the substances to be weighed. For adding or removing small quantities of powders during weighing, a slip of smooth hot-pressed writing-paper makes a very convenient spatula. Liquids are, of course, always weighed in a balanced glass or tube. The final adjustment is effected by means of a piece of glass tube drawn out at one end to a point, with which a minute portion of liquid may be taken up and allowed to flow out drop by drop.

Weights for chemical purposes should be made of brass, or preferably of platinum. They must be carefully protected from damp, acid fumes, or anything which might corrode or soil them, and for the same reason they should never be touched with the fingers, but lifted with a pair of forceps, kept for the purpose.

Bodies should never be weighed whilst hot, as the current of heated air makes them appear lighter than is actually the case. Volatile and deliquescent bodies, which might either lose or gain weight during the operation, are best weighed by being transferred into a portion of water previously balanced, the increase of weight being then noted. For counterpoising glasses, capsules, &c., small shot, slips of sheet copper and lead, tinfoil, and bits of paper, will be found convenient. Should the two arms of the balance be unequal, it may still be safely used, by resorting to the method of double weighing, invented by Borda. The body to be weighed is placed in one scale, and counterpoised by means of small shot, &c., in the other. It is then removed, and weights put in its stead until the equilibrium is restored.

MEASURES.

Liquids and gaseous bodies are often measured in graduated tubes and glasses, the use of which requires few precautions.

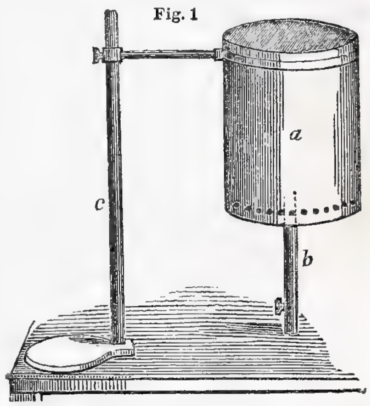
The accuracy of the graduation should always be carefully verified.

SOURCES OF HEAT.

One of the greatest modern improvements in chemical apparatus is the use of lamps in the application of heat. It is only in a few instances where a very high temperature is required, that a furnace is indispensable.

Two kinds of oil-lamps are employed—the common, and the argand. The former yield but a very moderate heat, but when carefully trimmed and shielded from currents of air by one of Griffin's stoneware lamp cylinders, they will burn for 12 or 16 hours. They are, consequently, very useful for slow digestions, evaporations, &c. The argand lamp produces a higher temperature, especially when furnished with a double concentric wick. It is, therefore, serviceable for boiling moderate quantities of liquids, distilling, subliming, &c. The spirit-lamp, which is much employed on the continent, is of very little value in England, owing to the exorbitant price of alcohol. In its stead, we employ the still more efficacious gas-furnace (fig. 1). A cylinder, *a*, of sheet iron or stoneware, provided with a number of circular apertures near the bottom, is covered at top with a grating of wire-gauze, impervious to flame. Below is a pipe and tap, *b*, for admitting and regulating the supply of gas. This pipe may either rise from the work-table, or be attached to a coil of flexible tubing. The cylinder is supported at any requisite height by means of the retort stand, *c*. The coal-gas mixes with common air within the cylinder, *a*, and is kindled *above* the wire-gauze. It burns with a pale blue flame and an intense heat, and serves for igniting platinum and porcelain crucibles, and for boiling and distilling on a larger scale, or at higher temperatures, than can be effected with the argand lamp.

Fig. 1

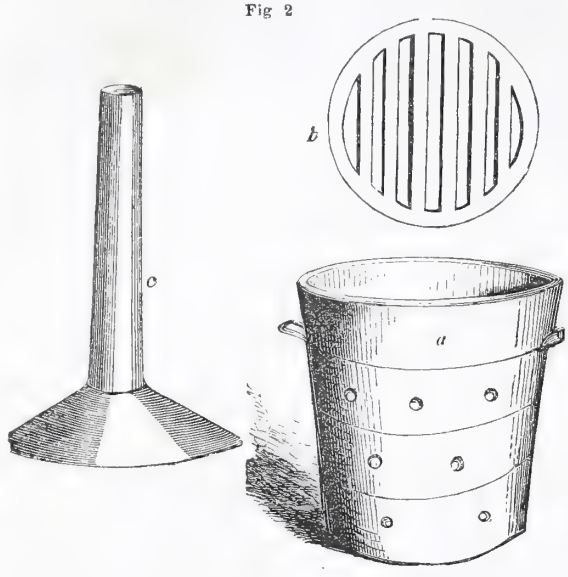


Whatever be the source of heat employed, glass vessels can rarely be exposed to the naked flame without risk of breakage. A sand or water bath is generally employed. These are vessels usually made of sheet-iron or copper, and filled with sand or water, in which the vessel to be heated is placed. The heat is thus transmitted in a more regular and gradual manner. When a glass vessel must be exposed to the naked fire, the temperature should be raised as gradually as possible.

Where the amount of room at the disposal of the student is

limited, a very useful furnace may be made out of one of those large crucibles known as blue pots. For this purpose, the pot, *a* (fig. 2), is pierced with round holes, at equal distances from each other, about 1½ inch in diameter, and arranged in three rows, as shown in the figure. It is then bound about with stout copper wire in three different places; above the upper holes, between the upper and middle, and between the middle and lower. Two loops of wire should be left at opposite sides to form a handle. A round grate of cast-iron, *b*, may be placed so as to rest between the second and lower row of holes. The action of such a furnace may be con-

Fig 2



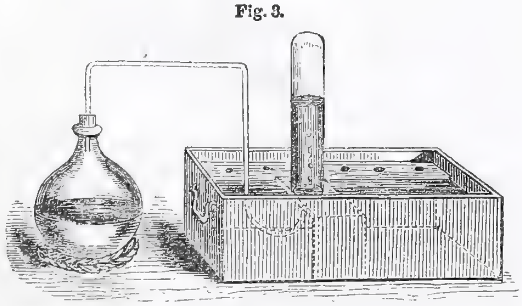
siderably improved, by placing over it a sheet-iron dome and chimney, *c*, as shown in the figure. The proper fuel is charcoal.

The construction and nature of more complicated chemical furnaces will be described in another article.

PNEUMATIC TROUGH.—PREPARING AND COLLECTING GASES.

The method of collecting gases, as invented by Priestley, depends upon a few very simple principles of natural philosophy. If we fill a tumbler and invert it in a bowl of water, we may raise it up until the mouth is almost upon a level with the surface. The pressure of the atmosphere upon the surface of water in the bowl, hinders that in the tumbler from descending. If we now blow air through a pipe into the water, it will ascend

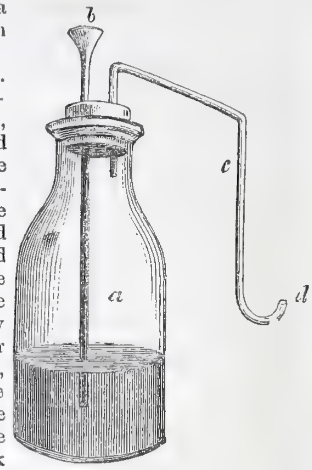
Fig. 3.



to the surface in bubbles; and if this take place under the inverted tumbler, the bubbles will rise up to the top, and gradually displace the water.

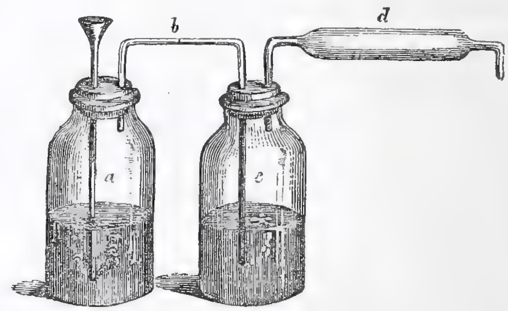
This simple arrangement, modified in shape, but involving no new principle, is the pneumatic trough represented in fig. 3. It is generally an oblong box of japanned sheet-iron or copper, varying in size according to the size of the receivers to be employed. There is a moveable shelf, upon which the gas jars stand with their mouths below the surface; it is pierced with apertures, to allow the ascent of the gas bubbles from the beaks of retorts, &c., into the jars. The method of using the trough is as follows:—Water is poured in until it stands about an inch above the shelf. The jars, or receivers, are then filled with water, and placed upon the shelf with their mouths downward. Directly underneath is placed the delivering tube of the vessel in which the gas is generated. This may be either a retort, or a flask or bottle fitted up with bent tubes.

Fig. 4.



The annexed apparatus (fig. 4) is well adapted for preparing hydrogen, carbonic acid, sulphuretted hydrogen, and other gases not requiring the application of heat; *a* is a wide-necked flask containing the solid ingredients, and closed with a good cork, perforated with two holes. Through the one passes a very small tube funnel, *b*, which reaches nearly to the bottom; through the other is inserted the delivering tube, *c*, which need not reach above ¼ inch into the flask, and whose outer end, *d*, is placed under the shelf of the trough. The cork is secured, so as to be air-tight, with soft cement. (See *Lutes*.) A mixture of acid and water is then poured down *b*, until it rises above the lower end of the tube. The gas liberated cannot escape through *b*, as its lower aperture is under water, and, consequently, issues in a stream from the delivering tube at *d*. If the action is too violent, the pressure within may cause the liquid to ascend in the tube, *b*, and even rise out at the top like a fountain. Great care must be taken to select good, sound, elastic corks, to fit them well in their place, and to

Fig. 5.



secure the joints accurately with cement, otherwise failures will often occur.

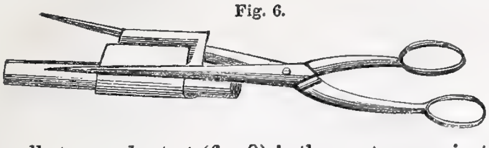
In certain delicate experiments, gases, before being collected, require to be washed and dried, in order to free them from certain impurities. For this purpose, the arrangement represented in fig. 5 is adopted: *a* is a generating flask, fitted up as in fig. 4, except that its delivering tube, *b*, is passed through the cork of a second flask, *c*, and descends nearly to the bottom. This flask is partially filled with water, which frees the gas from a variety of impurities. Out of *c* the gas passes into *d*, a wide tube filled with fragments of chloride of calcium, whence it may be led by bent tubes in any direction required.

As tubes of the form, *b*, are apt to break from their rigidity, a caoutchouc joint may be inserted. These joints, which are highly useful in connecting tubes, are very easily made. A piece of sheet caoutchouc, about 1½ inch square, is folded loosely round a rod of the same diameter as the tubes which it is designed to connect. The spare edges are then cut off with a pair of clean sharp scissors at one stroke, as shown in fig. 6. If this is adroitly performed, the newly-cut edges cohere, and

when slightly pressed together with the thumb nails, the suture becomes perfectly air-tight.

When gases require the use of heat in their preparation,

Fig. 6.



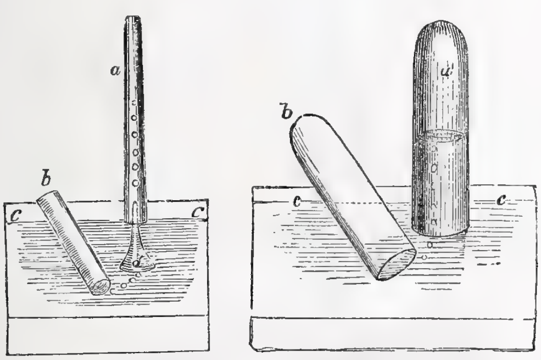
a small stoppered retort (fig. 8) is the most convenient. We may here mention that hard or heavy bodies should never be allowed to fall into a retort perpendicularly, but be allowed to slide gradually down the sides until they reach the bottom.

Whatever apparatus we use in generating gases, the first portion that passes over will be impure, being mixed with the air contained in the vessel. It should, therefore, be allowed to escape, or collected in a separate receiver. Hydrogen, olefiant gas, and a few others, when thus mingled with common air, are dangerously explosive.

As soon as a receiver is full, it may be removed from the shelf, and, by inserting a saucer beneath the mouth of the jar, without raising the latter above the surface, may be transferred altogether from the trough, and set aside for use. It must be remembered, however, that gases cannot thus be preserved for an indefinite length of time. The water by which they are confined secures them indeed from direct contact with the atmosphere, but by alternately absorbing, and again evolving, at every slight change of temperature, small portions, both of the outer air and of the gas within, an interchange is gradually effected, and the receiver will ultimately be found to contain very little of the original gas.

It is often necessary to transfer portions of gas from one receiver to another, or to a tube. For this purpose, the vessel into which the gas is to be led is filled with water, and held in a perpendicular position, with its mouth downwards, and below the surface. The vessel containing the gas is then brought up to it, and gradually inclined with its mouth below the aperture of the other vessel, so that the bubbles of gas may ascend into the latter. In the appended sketch (fig. 7), *a*

Fig. 7.



represents the receiving, *b* the delivering jars, and *c c* the water level. If the receiving vessel be very narrow, a funnel must be used as at *d*.

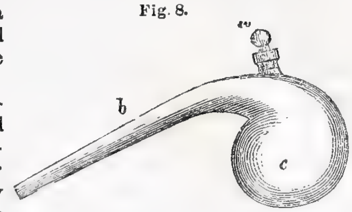
Certain gases, however, such as ammonia, hydrochloric acid, and cyanogen, are either decomposed or absorbed by water. Such are collected over mercury. The mercurial trough is made of iron or stoneware, and, on account of the weight and expense of the material, is usually of small size. On account of the great pressure, much care is required in securing all the joints of the gas-generating apparatus, and the extremity of the delivering tube must be brought exactly under the mouth of the receiving jar. Chlorine gas, which attacks mercury, is collected either over warm water or by displacement, the delivering tube being conducted to the bottom of a tall dry jar.

Water should not be allowed to remain standing in the pneumatic trough longer than absolutely necessary, especially if gases of an acid quality have been collected. For the purpose of letting it off, it is very convenient if a tap be inserted at the bottom.

DISTILLATION AND SUBLIMATION.

These two important processes consist in volatilizing a body by means of heat, and recondensing it. In the former, the product is a liquid; in the latter, a solid. The principal instruments used are retorts and stills. The former are glass, earthenware, or iron vessels, generally of a globular shape, provided with a stoppered orifice or tubulure, *a*, fig. 8, for introducing the substances to be acted upon, and a pipe, *b*, where the vapours escape; the lower part, *c*, is called the body of the retort. The retorts used in gas-works are large iron cylinders, to which iron delivering pipes are secured by screws. For preparing large quantities of oxygen gas, an iron mercury bottle, fitted up with copper-tubing, makes an excellent retort.

Fig. 8.



The vessel in which the products of distillation are collected, is called a receiver. It is generally a flask, of suitable capacity for receiving the neck of the retort.

If the product is very volatile, condensation becomes necessary. This is effected, either by placing the body of the receiver in a vessel of cold water or a freezing mixture, or by interposing between it and the retort an apparatus termed a condenser. This is a wide metal tube filled with cold water, which can be continually changed as its temperature rises. Along its middle passes a narrower glass tube, which conducts the vapours from the retort to the receiver.

Stills are large pans of tinplate, copper, or sometimes of platinum, fitted up with a dome or cover of the same materials, terminating in a delivery pipe. Condensation is generally effected by means of a spiral tube called a *worm*, immersed in a large vessel of cold water.

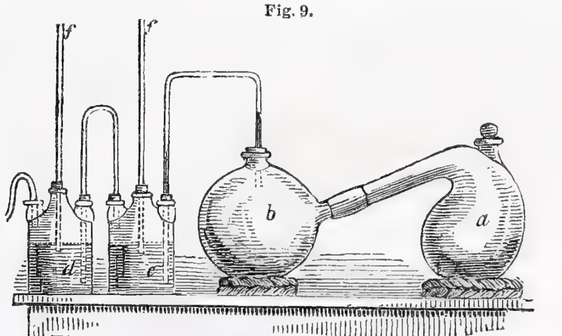
The apparatus for sublimation is more simple. The materials are placed in a flask, over the neck of which is luted another larger flask, to receive the product. An aperture must be left to allow the rarefied air to escape.

SOLUTION.

Few directions are here needful. The body to be dissolved is reduced to powder, and gradually added to the solvent, frequently stirring. If a saturated solution is desired, the solvent should be heated, and, if volatile, enclosed in a stoppered flask. All solutions, before being put aside for use, should be filtered.

To saturate water, or any other liquid, with gases, the arrangement called Woulfe's apparatus is in use. It consists of a series of three-necked bottles, each about half filled

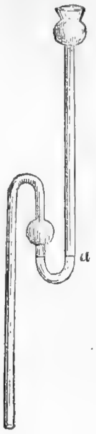
Fig. 9.



with the solvent liquid, and connected as in fig. 9. The gas from the retort, *a*, or the receiver, *b*, is led by a bent tube, *t*, in at the first aperture of the first bottle, *c*, and down to its

bottom. The portion which escapes solution is carried off by a tube adapted to the third aperture, which conducts it down to the bottom of the second bottle, *d*. To the central aperture of each bottle is fitted the straight tube, *f*, or a curved tube (fig. 10), named, from its inventor, Welter's Safety Tube. This is to prevent the liquid contained in one bottle from being driven over into the next, in case, by too rapid absorption, the internal pressure should become less than that of the external atmosphere. The bent part of the tube, up to *a*, is filled with mercury, through which the air, in such cases, forces its way, and restores the equilibrium.

Fig 10.



DIGESTION.

In order, either to dissolve a substance entirely, or to extract and remove some one or more of its constituents, it is frequently digested, that is, exposed for a considerable time to the action of a solvent at elevated temperatures. This operation may be performed either in an open dish (evaporating basin), or, if the solvent be very volatile, in a flask. If it is desirable to prevent the temperature from rising beyond a certain point, a water or solution bath should be employed.

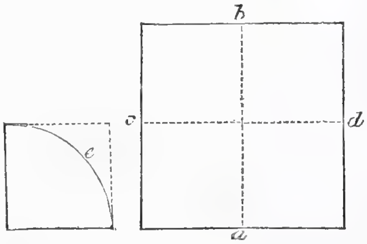
FILTRATION.

For filtration are required funnels, filter-paper, and a filtering stand.

Funnels are conical vessels of glass or porcelain, of such a shape that, if cut perpendicularly, the section would represent an equilateral triangle. Funnels should be made of very hard, smooth, insoluble materials, in order not to be attacked by the liquids passing through them. Those provided with ribs or grooves in the inside, allow the liquid to run through more rapidly, but plain ones are preferable whenever prolonged washing is required.

Good filter-paper is a rare article. It should be thin, light, free from mineral matter, not inclined to adhere to solid substances dried upon it, and, whilst it allows liquids to pass through with moderate speed, it should retain all pulverulent matter. The best is manufactured in Sweden. In order to adapt it to the funnels, it is first cut in square pieces (fig. 11); it is then folded, so that *a* may lie upon *b*, and again, so that *d* comes upon *c*. The loose edges being now trimmed off with scissors, there remains a cone, *e*, exactly fitting the funnel.

Fig. 11.



Certain liquids, however, would be soiled or partially decomposed by contact with organic matter. In such cases, we first fill the throat of the funnel with some fragments of clean glass or porcelain, and then fill up the interstices with a tuft of so-called mineral flax, or asbestos.

The filtering frame is merely a board, supported on legs about 18 inches in height, and pierced with a number of holes from 2 to 4 inches in diameter, and 5 or 6 inches apart. Beneath, stand vessels to receive the clear liquid that drains through.

When filtration is intended not merely to clarify a liquid, but to obtain a solid in a state of dryness and purity, washing is requisite. The solid, as it lies in the filter, is drenched with distilled water until the last portion of the liquid with which it was associated is expelled. For this purpose, the washing-bottle is employed. This is generally a wide-mouthed bottle or flask (fig. 12), fitted with a cork having two apertures. Through one of these is passed a tube, *a*, which only just enters the flask, and is bent above so as to form a convenient mouth-piece. Through the other aperture passes a tube, *b* reaching to the bottom of the flask, bent above at an acute angle, and drawn out to a fine point, as in the figure. On filling the flask with

Fig. 12

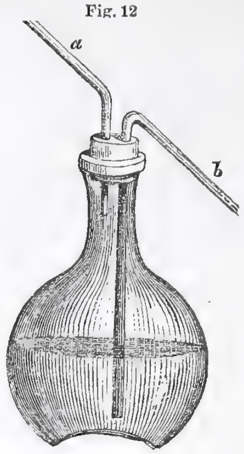
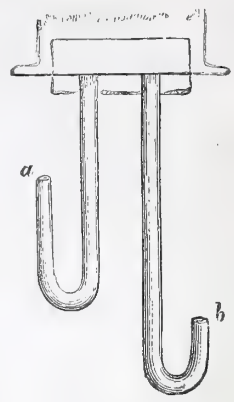


Fig. 13.

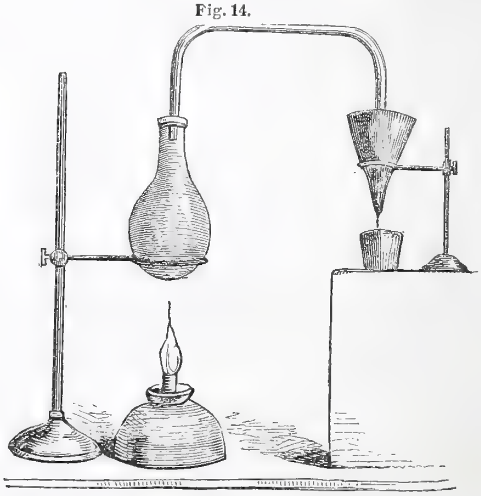


distilled water, and forcing air in at *a* with the mouth, the water is driven out at *b* in a fine jet.

A self-acting washing-bottle is shown in fig. 13. Two bent tubes, *a* and *b*, are passed through the cork of a flask containing water, which is then supported in an inverted position over the substance to be washed. Air enters the bottle through *a*, whilst water trickles out at *b*.

For those substances which can be washed in warm water without injury, a very simple and convenient arrangement has been suggested by Dr. Shier. The funnel containing the filter and precipitate is covered over with a glass plate, with a hole in its centre, through which passes a bent glass tube, adapted at its other extremity to a flask containing water (fig. 14). When heat is applied, the water in the

Fig. 14.



flask distils gradually over into the funnel, and is all the more efficacious, as a part of it arrives uncondensed, as steam.

As we have already intimated, the liquid ordinarily employed in washing is distilled water. In some particular cases, alcohol, or highly dilute acids, or ammonia, must be employed.

DESICCATION.

The expulsion of the water which adheres to the particles of a solid body, is a frequent and important operation. The ordinary agent employed for this purpose is heat, regulated by the employment of a water, steam, or air bath. A convenient air-bath is shown in fig. 15. *a*, *a*, is a cylindrical vessel of thin sheet copper, with a moveable lid, provided with apertures, *b*, *b*, through which thermometers are thrust to ascertain the temperature. The substance to be dried is placed in a capsule

supported on the wire ring, *c*. The entire apparatus is heated by being set over a gas-lamp, which is regulated according to the indications of the thermometers.

Fig. 15.

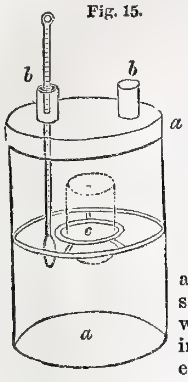
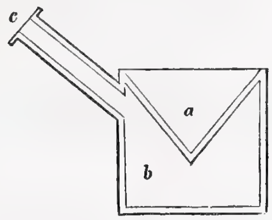


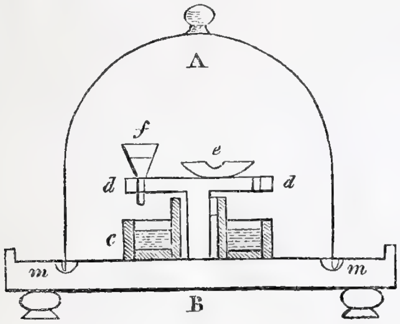
Fig. 16.



A water-bath for drying precipitates along with the filter, is represented in section in fig. 16. The cavity, *b*, is filled with water, the filter with its contents fits into the conical part, *a*, and the steam escapes at *c*, which serves also as a handle. This apparatus is made of Berlin porcelain, and is heated over the gas-lamp.

Many substances, however, require to be dried, which would suffer injury from the application of heat. Such are desiccated by being placed under the receiver of an air-pump, along with a capsule containing sulphuric acid. As the receiver is exhausted, the diminished pressure allows evaporation to proceed more rapidly from the moist body, whilst the vapour, as fast as formed, is absorbed by the sulphuric acid. The same object may be attained, nearly as well, without an air-pump, by the aid of the apparatus in fig. 17. A is a bell-glass fitting into *m m*,

Fig. 17.



a circular groove cut in B, a circular disc of hard wood, well varnished; the groove contains mercury, so that the space within the bell-jar is isolated from the external atmosphere. *c* is a flat dish filled with sulphuric acid; *d d* is a stand rising over *c*, and intended to support the objects to be dried, such as the capsule, *e*, the funnel, *f*.

PULVERIZATION.

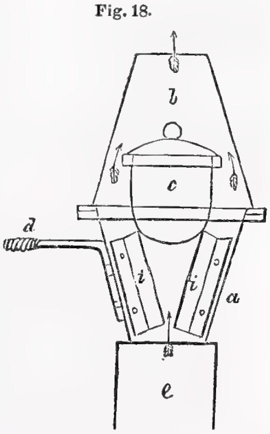
In order to facilitate chemical reaction, it is generally necessary to present all solid substances in a state of minute division. To this state they are usually reduced by grinding in the mortar. The best mortars are made of agate, but such are usually of a small size, and only suitable for minute experiments. Excellent mortars are made of Berlin porcelain; they are exceedingly hard and dense, little affected by reagents, and easily cleaned. They are, however, brittle, and though capable of sustaining any amount of grinding or rubbing, they will not bear hard blows. They improve with use, as the bottom and sides become slightly roughened, and thus retain the substance to be ground under the pestle. Wedgwood mortars are inferior, but still very useful. The pestle should be of the same material as the mortar, and should be all in one piece. Metal mortars are rarely used, as they quickly suffer abrasion, and thus contaminate the bodies pounded. The manner of pounding differs according as it is wished to reduce the body to a coarse or a fine powder. In the former case, the pestle is grasped lightly, and allowed to fall upon the body by its own weight, all grinding being avoided. If a fine powder is required, the pestle is grasped firmly, and forced obliquely down on the side opposite to the operator, the mortar being turned a little way round with the other hand at every stroke, so as to bring the whole of the matter in succession under the pestle. When the mass has been in this manner reduced to moderately fine fragments, the action is changed, and the pestle is carried round in circles, beginning at the centre, and gradually expanding towards the circumference. On reaching the exterior of the mass, the circles are again contracted, and the operation continued in this manner until the whole is sufficiently fine. It is better not to reduce one portion to an impalpable powder, whilst the rest remains in coarse fragments, but to work regularly and gradually upon the whole mass. If the substance be required in very fine powder, only a small portion should be ground at once.

If the substance is exceedingly hard, before being introduced into the mortar it may be wrapped up in a piece of brown paper, and crushed with a few blows from a hammer. Flints, and many other minerals, are more easily pulverized if previously heated to redness, and quenched in water. Charcoal is most easily pounded whilst hot. Camphor must be moistened with a few drops of alcohol. Glutinous organic bodies may often be pulverized with the addition of clean quartz sand—a method, of course, practicable only in those cases where its presence would occasion no inconvenience. It should be borne in mind that many substances, when pulverized, become exceedingly hygrometric, or absorb moisture from the atmosphere to an extent which greatly increases their weight. Substances for analysis should be pulverized first, and the requisite portion weighed out afterwards. When the metals are required in a state of minute division, they must either be employed as foil, or as filings. The files used in preparing the latter should be very clean, one being reserved for every kind of metal. The more precious metals may be obtained in very fine powder, by being precipitated from their solutions by means of reducing agents.

CRUCIBLES—IGNITION—FUSION.

The vessels used for submitting bodies to the action of an intense heat, are called crucibles. They are usually of a conical shape, and are made of fire-clay, porcelain, black-lead, iron, or platinum, according to the object in view. The best fire-clay crucibles are the Cornish and the Hessian. These are hard, dense, and very infusible. Many substances, however, when in a state of fluidity, penetrate into the body of the crucibles, which renders them incapable of being cleansed. Hence they can only be used once, except for a repetition of the same process. Black-lead crucibles are little affected by sudden changes of temperature, and resist the action of fluxes. They must not be employed in any case where iron or carbon might prove injurious. Crucibles of Berlin porcelain bear a very high temperature, and do not allow the escape of liquefied bodies. From this cause, joined to the smoothness and density of their surface, they are well adapted for analytical operations. They may be obtained either stout, suitable for furnace operations, or thin, for weighing and ignition over the gas-lamp.

Fig. 18.



Crucibles of platinum are the most generally useful in analytical experiments. They should be heated either over the gas-lamp, or in a furnace fed with charcoal alone Crucibles of silver and of pure gold are also occasionally employed. The latter have the advantage over platinum in resisting the

action of caustic alkalies, but they are softened by a comparatively low temperature. In metal crucibles no metal should be heated, nor any easily reducible metallic compound, otherwise a fusible alloy will most probably be formed, and the vessel with its contents be lost. In heating platinum crucibles over the gas-lamp, much advantage is derived from the use of the crucible jacket, a socket of thin sheet-iron (fig. 18.)

a represents the lower part of the jacket, fixed upon the upper cylinder of the gas-lamp, *e*, and containing three iron supports, *i*, upon which the crucible, *c*, rests. *b* is a dome or cover to confine the heat, and *d* the handle. The arrows show the direction of the flame and hot air. Whenever a crucible requires the application of prolonged heat, it should be supported, not upon the fuel, but on a cylindrical stand of fire-brick, or some similarly infusible material, resting upon the bars of the furnace beneath. The furnace should be carefully regulated, and fresh fuel supplied gradually, so as to avoid any sudden alternations of temperature.

CEMENTS AND LUTES.

In arranging chemical apparatus for use, lutes and cements are continually needed for rendering the various joints airtight. Of these mixtures, several are in use, and should be kept on hand in the laboratory. For joining together tubes with corks, where heat is not applied, the so-called *soft cement* is exceedingly useful. It is made by putting into an earthen dish some yellow wax, with as much oil of turpentine as will serve to dissolve it, and setting the dish in a warm place until the mixture melt. When quite liquid, finely powdered red ochre is stirred in until the mass appears to have the desired consistence. The more turpentine is added, the softer and more fusible the cement becomes.

For connecting apparatus which must be exposed to high temperatures, so-called *fat lute* is employed. It is made by mixing dried pipe-clay with linseed oil. It should be applied very closely to the joint, and secured by strips of bladder, tied down with packthread. Clay beat up with water is, in many operations, a useful lute, but if suddenly heated, it is apt to crack and fall off. Pieces of bladder soaked in water until they become glutinous, and then smeared over with white of egg, are often very serviceable in connecting tubes. They should be tied down with string. Linseed meal, stirred up with water, milk, or thin glue, forms a lute which will resist the action of most vapours. It will not, however, bear the contact of water, and is destroyed by temperatures exceeding 600° Fahr. Hard cement is made by melting together one part of yellow wax, and five parts of resin, and stirring in one part of finely-powdered red ochre. It serves for securing metal caps, taps, &c., to glass jars and tubes.

Glass vessels, such as flasks, retorts, and tubes, frequently require coating with lute, to enable them to resist a very elevated temperature. For this purpose, the best fire-clay, made into a paste with water, is employed. The lute is wrought out into a thin cake, and then gradually moulded over the glass, taking particular care that no air-bubbles remain enclosed in the mass. The thickness of the coating should be from $\frac{1}{3}$ to $\frac{1}{4}$ of an inch. The whole is then allowed to dry very gradually at a gentle heat. To prevent the lute from cracking and falling off whilst being dried, it is often mixed with hay, cut to the length of half an inch.

WORKING IN GLASS.

Experimental chemistry would prove at once tedious and expensive, were the student obliged to purchase every piece of apparatus in the exact shape in which it is required. But with a little attention, he may acquire the art of bending and cutting glass tubes so as to suit his purposes. The chemical gas-lamp, or an ordinary gas-burner urged with the *blowpipe* (as afterwards described), is a sufficient source of heat for these operations. If it is desired to bend a glass tube, it should be grasped steadily but lightly, and held across the flame, turning it round, and moving it gradually from end to end, so as to heat the part intended to be bent for the length of two or three inches. When the glass begins to yield, a gentle pressure is applied with both hands, bending the tube gradually, until it takes the designed shape. If a sharp and sudden bend is preferred, the heat should be concentrated more upon one point; but if a gradual curvature is intended a greater length of the tube is exposed to the flame

To close up the extremity of a tube, so as to form the useful instrument known as a test-tube (fig. 19), is rather more difficult.

Fig. 19.

Fig. 20.

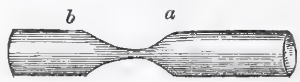


Fig. 21.

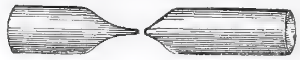


Fig. 22.

A piece of tubing should be taken, sufficiently long to form two, and heated in the middle, confining the heat to a narrow ring. The hands are then separated a little, when the tube will assume the appearance shown in fig. 20. The tubes are now moved to the extremity of the flame, and the portion in the right hand, *b*, is used as a moulder to finish the other portion. The flame is therefore brought to bear upon the part which is to be the bottom of the closed tube, *a*, whilst the right hand is gradually withdrawn, until the two portions separate, and *a* remains in the form shown in fig. 21. The tube is still unfinished. It is uneven, and there is generally a little knob of glass at the bottom. To remove this, the bottom is heated until the glass softens; then applying the lips to the open extremity of the tube, air is gently forced in until the heated part expands, and the knob disappears.

If it is required to seal up a tube without regard to its form, the extremity is simply heated, turning it round until the sides collapse and adhere together.

Whenever glass has been bent or sealed, it should be allowed to cool very gradually. If this precaution be neglected, it becomes so brittle as to be worthless.

In cutting glass rods and tubes into lengths, there is little difficulty. A deep mark is made entirely round the tube with a sharp three-square file, and the tube is then snapped by pressure with both hands. If it does not yield at the first pressure, the mark should be deepened.

CORKS.

The use of corks no longer consists merely in closing up phials. So extensive indeed is the application of this material, that Liebig enumerates cork, along with glass and platinum, as the three most valuable substances in the hands of the chemist. In connecting apparatus, great care should be taken to select good sound corks, the employment of which often renders lutes and cements unnecessary. To adapt them to the apertures in which they are to be inserted, they are trimmed with a sharp knife and finished off with a rasp. When required to be perforated, a set of instruments, called cork-borers, are employed. These are brass tubes, of different diameters, corresponding to the ordinary sizes of glass tubing, and sharpened at one end. One of these, of the proper size, is forced gradually and steadily through the cork. The cutting edge of the borer should be kept sharp, and be smeared with a little oil or lard. If an aperture is required nearly as large as the cork itself, the latter, before being pierced, is wrapped tightly round with twine, which will make it less likely to burst on the introduction of the borer.

GENERAL REMARKS.

We shall conclude this chapter with a few observations which may be of service to the young experimentalist. A blank book should always be kept at hand, in which the result of every experiment should be entered *at the time.* It is improper to defer the entries until the close of the day, or the termination of a train of experiments, since there may then be some difficulty in remembering the precise order of the phenomena, and any doubt which may arise in the mind cannot then be decided by re-examination. Every substance or solution that is set aside or subjected to any protracted process, such as evaporation, desiccation, washing, &c., should be carefully labelled. From the neglect of this precaution, many valuable results have been lost. Every circumstance that can possibly bear upon the issue of an experiment, should be carefully noted down. Time spent in this manner is never thrown away. If any new or otherwise remarkable phenomenon presents itself, the experiment should be repeated again and again, with all such precautions as the case may suggest. In examining an unknown body, or the products obtained by treating a known substance in some new and hitherto untried manner, it is proper to proceed methodically. One product should be thoroughly examined before another is taken in hand. As a general rule, Faraday advises that precipitates should be first investigated, and liquid residues afterwards. On commencing an experiment which requires close attention, all the various articles requisite should be arranged beforehand, that no delay may afterwards ensue. If, on the addition of a reagent to some body under examination, no immediate change is produced, we are not, on that account, to infer that there is no action. By allowing the whole to stand for some time undisturbed, new and important phenomena have frequently been made manifest. A particular place in the laboratory should be appointed where such substances may stand.

Beginners are often at a loss how to occupy the time during the performance of certain protracted operations which only require occasional inspection. Such intervals may be very profitably employed in examining the labels and stoppers of stock and test phials; restoring the former if effaced, dusting the shelves and bottles, cleaning soiled apparatus, &c. All beaker glasses, evaporating basins, &c., should be kept in an inverted position, and the pipes of funnels, ends of safety tubes, &c., should be covered with a bit of paper, twisted into the form of a cone or thimble. Without constant attention to these minutiæ, it is vain to look for perfect accuracy in the results of our experiments, and, without perfect accuracy, chemical research is utterly valueless. There is, in our opinion, no better school of patience, perseverance, and system, than the laboratory.

DYNAMOMETRICAL APPARATUS FOR MEASURING THE AVAILABLE POWER OF MARINE ENGINES.

BY M. COLLADON, GENEVA.

The process proposed by M. Colladon consists in measuring the force of horizontal traction exerted by an engine in a vessel made fast to the quay, and working in given conditions to be afterwards stated.

The number and depth of the paddles—their length from the axis—the normal pressure of the steam in the boiler—and all the other details having an influence on the speed of the ship, ought to be previously well ascertained, to obtain the most regular and uniform rate of working. The vessel is then put in motion in calm weather, and when the speed is found to be uniform, and the tension of the steam nearly constant, a note is taken of the number of revolutions of the wheels in a given time, and the height of the manometer.

With a knowledge of these numbers, the dynamometric apparatus may be applied in smooth water and calm weather.

To proceed to operate with it, the depth of the paddles immersed must be diminished by a quantity proportional to the size of the vessel, and, generally, about three-fifths of that depth.

The wheels being thus adjusted, the vessel is fastened by the stern to a ring on the quay, at a place where the depth of the water is at least double the draught of the vessel. It is desirable, for accuracy of measurement, that the boat be placed in an isolated position, at a distance of at least forty yards from the point to which it is lashed.

The boilers are then heated, and, when the steam has acquired its normal pressure, the valves are opened by degrees, and the engine is worked with caution for four or five minutes. When assured that the mooring-cable operates properly, the valves may be opened, and worked at full steam.

If the proportions of the vessel do not much differ from those which are at present generally adopted by builders for large steamboats, the number of turns of the wheels will be nearly the same as that which had been already noted during the trial trip of the vessel, before the diminution by three-fifths of the depth of the paddles under water. If the number of turns is greater or less, the engine must be stopped, and the paddles brought a little nearer to the centre, or moved a little further off, till the normal speed be attained as nearly as possible.

The mooring-cable is then applied to one or several dynamometers, to measure the force by which it is drawn; it is obvious that the actual force in this case will only be indicated by the dynamometer, provided the traction is exerted horizontally; but as this condition cannot be always easily obtained, it will be necessary, when it is not so, to measure the angle formed by the cable with a horizontal plane, and then the horizontal traction will be obtained by the formula,

$$T \times \cos. a,$$

T expressing the tension indicated by the dynamometer, and a the angle of the cable with the plane of the horizon.

If the horizontal traction, expressed in lbs., be multiplied by the speed per second, expressed in feet, from a point taken on the outer edge of a paddle, after the diminution by three-fifths, a product will thus be obtained, which, divided by 246, will express, to within one or two hundredth parts, the true regular force of the engine.

Moreover, the experiment may be continued as long as desired, to measure the quantity of fuel consumed in a given number of hours—only care must be taken to use the fuel alternately from each of the two coal-stores, so as not to derange the equal immersion of the two wheels, or at least the position of equilibrium of the vessel which gives the required number of turns.

The apparatus first proposed by M. Colladon consisted chiefly of a kneed lever, to the short arm of which the traction was applied directly, and the dynamometer to the other. These arms being inclined to each other, the lengths of the levers could not be taken in an absolute manner for the whole experiment, and this rendered necessary a difficult correction in practice. To obviate this, the inventor has devised an apparatus which indicates, without any correction or calculation, the force of traction measured horizontally. This apparatus is represented in the annexed figures.

Fig. 1 is a side elevation of the machine; fig. 2 a front elevation; fig. 3 a horizontal section, following the line 1—2 in fig. 1; fig. 4 a horizontal section, forming a continuation of fig. 3; and lastly, fig. 5 is a vertical section of fig. 4.

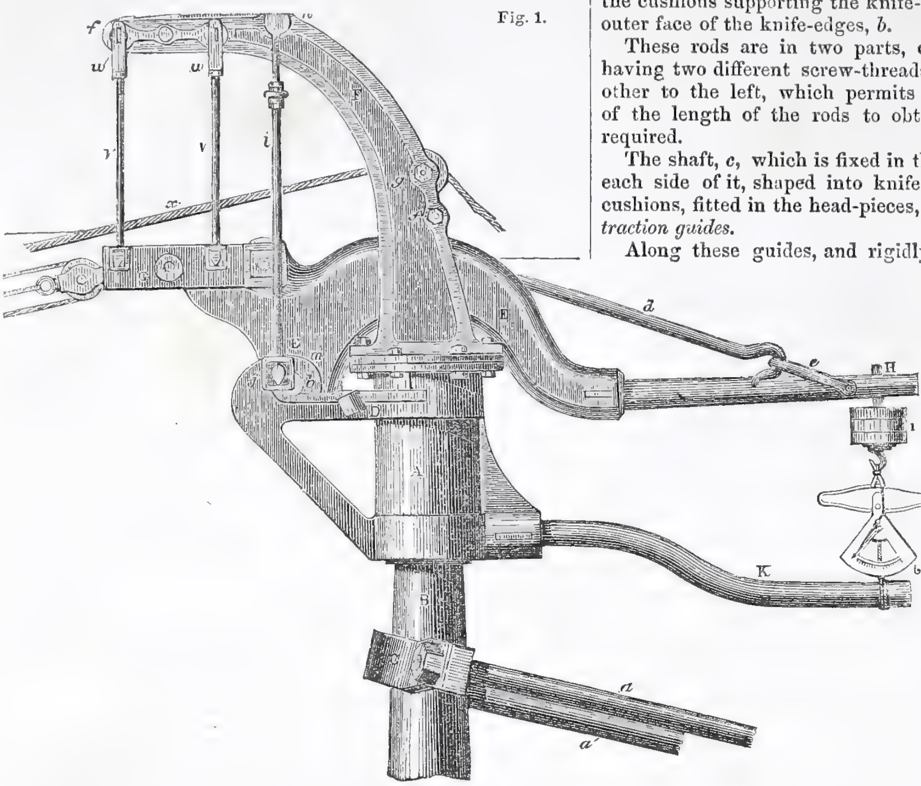
A is a strong drum of cast-iron, turning on the upper extremity of an iron shaft, B, the length of which, about twelve feet, is partly sunk in masonry, and rests in a socket below.

Near the middle is fixed a strong wrought-iron collar, C, carrying two ears, to which are fastened two cross-rods, a, the object of which is to prevent the deviation of the shaft, B, when the apparatus is in operation; these rods are secured at their extremities in masonry, like that in use for the mooring-chains of suspension-bridges.

In the drum, A, are fitted two brass cushions, against which the shaft rubs when the machine is made to turn.

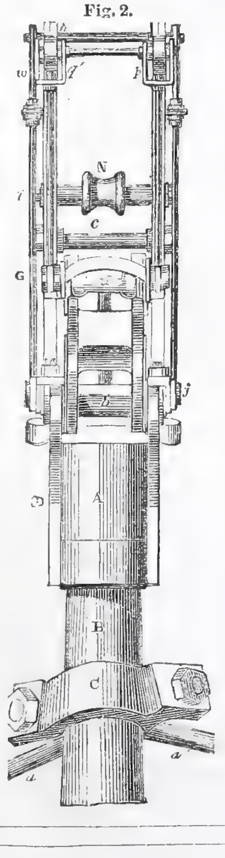
From the body of the drum project two brackets, D, ending in a bent part, to which are fitted steel cushions, supporting

Fig. 1.



the knife-edges of the shaft, *b*, keyed in the inferior eye, *m*, of the balance-beam, E.

Fig. 2.



Above is another eye, *n*, for receiving the shaft, *c'*, which terminates in knife-edges, *c*, at its two extremities.

The beam is of cast or wrought iron, and consists of two cheeks united by cross-bars. It terminates in a strong iron lever, H, to which are suspended either a counterweight, I, or one or more dynamometers, with or without a counterweight.

The drum, A, has also a collar, on which is fitted the lever, K, rigidly connected with the lever, H, in the manner denoted in the figure, or by a similar arrangement.

When the beam is of cast-iron, the lever, H, would be too unsupported, and might yield to the pressure. To obviate this, it is connected to the beam by the rod, *d*, bolted to a slot in the beam, and hooking into a ring fixed to the lever, H. By this arrangement the bending of the lever can always be avoided, and, by means of the hollow screw in the beam, it is easy to give to the rod, *d*, any degree of tension required

To the upper part of the drum are fixed two brackets, in which are fitted the two cranes, F, leaving between them an interval sufficient for the free passage of the beam. Cross-bars, *f*, *g*, and *h*, keep them separated to this extent in their whole height.

The cross-bar, *h*, is prolonged on each side of the cranes, to receive the suspension-rods, *i*, the lower parts of which terminate in squares, for adjustment to the cushions supporting the knife-edges, *j*, which rest upon the outer face of the knife-edges, *b*.

These rods are in two parts, connected by a double nut, having two different screw-threads, the one to the right, the other to the left, which permits the convenient adjustment of the length of the rods to obtain the degree of suspension required.

The shaft, *c*, which is fixed in the beam, extends a little on each side of it, shaped into knife-edges, on which rest steel cushions, fitted in the head-pieces, G, which the inventor terms *traction guides*.

Along these guides, and rigidly connected with them, are fixed the four knife-edges, *l*, *o*, *p*, *q*, of the cross-bars, *r*, *s*, which keep them at the proper distance; a third cross-bar, *t*, supports the bridle, *u*, to which is attached the hook of the block, M, from which proceeds the mooring-cable of the vessel under experiment.

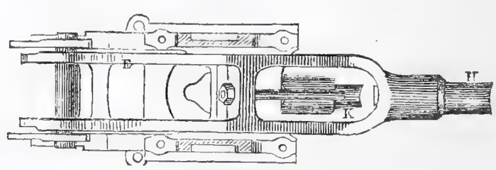
The knife-edges *l*, *o*, *p*, *q*, pass freely into the squares which terminate the suspension-rods, *v v'*, and rest on the steel cushions with which they are fitted.

The upper ends of the rods, *v v'*, are screwed into the lower parts of the pieces, *w*, *w'*; and the length of the rods can be regulated by means of the screws.

In each of the pieces, *w w'*, is fixed a knife-edge, which traverses freely the upper part of the crane, as shown in fig. 1. Cushions are fitted into eyes formed in the sides of the crane, against which rest the four knife-edges, *l'*, *p'*, *o'*, *q'*.

The object of the four rods, *v v'*, is to suspend the traction

Fig. 3.



guides, so that they may never be able to diverge from the horizontal position which they ought to maintain so long as the experiment continues, however great the lateral or downward strain tending to cause them to deviate.

Fig. 4.

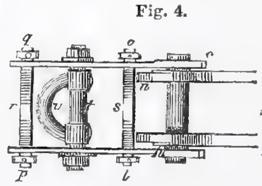
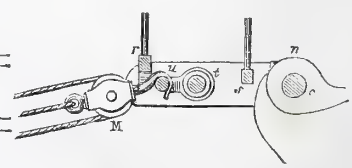


Fig. 5.



The two knife-edges, *b*, *j*, ought to be placed in the same horizontal line, perpendicular to the vertical plane of projection. The upper part of the lever, H, or the point at which the counterweight is suspended, must be in the horizontal plane, passing through the knife-edges, *b* and *j*.

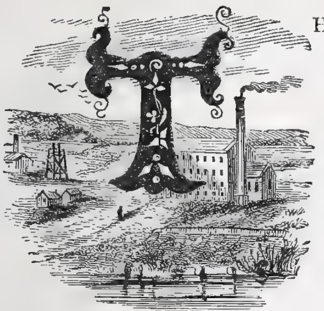
To facilitate the calculation of the levers, we have, in the figures, assumed the counterweight, I, to be placed at five times the distance from the point, *b*, as that between *b* and *c*. The knife-edges, *b* and *c*, should be in the same vertical plane.

THE COTTON PLANT,

As it might be attended with danger to put the apparatus at once in direct communication with the steamboat which forms the subject of experiment, the precaution is taken, before the mooring-cable, x, is stretched, to attach, in the first place, the block to that point of the vessel which may be deemed most suitable; the cable, x, after passing through the block, M, makes one or two turns on the pulley, N, the shaft of which, g, is fixed between the two legs of the crane.

Two men are then made to pull the cable, and it is only after being assured it is perfectly stretched that the wheels of the steamboat are made to revolve with a view to the experiment. By proceeding in this manner, no parts of the apparatus are subjected to risk of derangement.

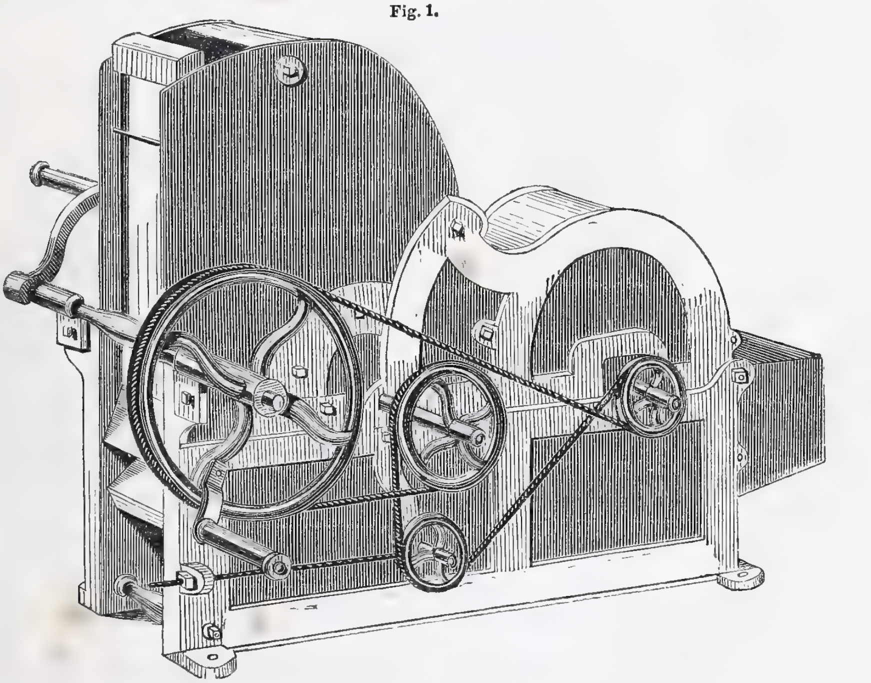
THE MACHINERY OF THE COTTON MANUFACTURE.



HE varied powers which are continually operating upon our national and social progress, embrace none that is more remarkable for the extent of its influence and the magnitude of its operations, than that branch of textile manufactures, the machinery of which it is the object of the present series of papers to illustrate and describe. Important as are the other branches of our manufactures, they must, in almost every point of view, give precedence to the Cotton manufacture. Viewed in its social aspect, it possesses an interest alike important to the political economist and philanthropist, and, in its commercial, it presents a striking picture of extended power and influence which no other branch of commerce can furnish. To aid the "genius of our manufactures," an enormous amount of commercial enterprise is continually at work, and the varied talents of our chemists and mechanicians are being continually pressed into her service. As has been most spiritedly and elegantly remarked, "England has gone to and fro upon the earth, and her sounding steps have been those of a giant. Her morning drum-beat following the sun, and keeping pace with the circling hours, compasses the earth daily with one continuous and unbroken strain of her martial airs;" and, doubtless, the most important influence which has placed her in this position has been that of our cotton manufactures. "The records of history," as a writer in the *Artizan* remarks, "fail to furnish us with a parallel to the wonders effected by its adherents—whether these have been the work of the capitalists who directed, and were the mainspring of its onward movements, or the mechanicians who assisted in the great work of her giant progress. Although its birth may be said to date from a period but a day ago in the history of man and his civilization, it is altogether astonishing to note the record of its progress. Truly it has changed the world's commerce, and given rise to a new era in the world's history." But leaving to other pens the task of chronicling the marvels of the cotton trade, viewed socially and commercially—of which, by the way, we have only to look around us to perceive the enormous magnitude of their influence—we shall proceed to detail the various mechanical processes through which the cotton is passed from the pod to the cloth, and the operations of that wondrous mechanism, without the aid of which the commerce of the manufacture must have been amazingly confined.

In another portion of this work, ample information is given as to the natural history of the cotton plant, and the various qualities used for the purposes of manufacture, and to that we refer the reader desirous of obtaining an insight into these valuable departments of the subject. We proceed, in accordance with the purpose of the present series, to explain the processes and machinery of the manufacture.

Fig. 1.



The first operation necessary, after gathering the pods, is to separate the cotton from the seeds. The simplest method of performing this operation is that practised in India. The cotton is placed upon a smooth stone, and an iron roller worked backwards and forwards on it.

The churka, or "roller gin," is another, and more advanced method. Two rollers revolve in opposite directions, two persons at opposite sides of the machine turning them by means of handles; in some instances, the periphery of the rollers is fluted, in others plain. The cotton pods are passed through

between the rollers, from one side to the other, by the revolution of the rollers. The seeds are thus separated and fall down on one side, the cotton being passed through to the other. This machine is calculated to do work at a very slow rate, 50 lbs. per day being the average of cotton cleaned.

The "saw gin" is another machine by which cotton wool is separated from the seeds, and is remarkably quick and effectual in its operations; by its aid a man may clean from two to three cwt. of cotton per day. It is almost universally used in America for this purpose; and its introduction has had a remarkable influence in extending the cotton manufacture in our country; for, without its aid, it is scarcely too much to affirm that the use of American cotton in Great Britain must have been so confined, as to have limited the manufacture to a very narrow basis of operations, whereas nearly the whole of our cloths are produced from American grown cotton. The "saw gin" was the invention of Mr. Eli Whitney of Massachusetts, United States of America, and was introduced in the year 1797. The following description, taken in conjunction with fig. 1, will give the reader an idea of its construction. A hopper of greater length than breadth, one side of which is composed of iron grating, formed by strong wires placed parallel to one another, one-eighth of an inch apart, is provided with a roller, revolving nearly in contact with the grating. On the central bar of this roller a series of circular saws is fixed, between which are placed several layers of wood, so as to keep the saws a distance of one inch and a half apart from each other. The cotton to be operated upon is passed into the hopper, and, sliding down the inclined grating, is caught by the teeth of the revolving saws and torn open; the wool, separated from the seed, is dragged through the grating, the seed shooting down the grating. The cotton, which adheres to the teeth of the saws, is taken off by a revolving brush, running in an opposite direction to the saw roller, and by means of the current created by the rapid revolution, is delivered at the other side of the machine.

The British saw gin is an improvement upon Whitney's, and is constructed entirely of iron, with the exception of the front hopper board. The entire weight of the machine thus constructed is about a ton, its cost varying from seventy to eighty guineas. The space it occupies is about six feet square, and may be worked by horses or bullocks. When worked by four bullocks, each pair working nine hours, it is calculated to clean fully 20 cwt.; but reckoning 7¼ lbs. of seed-cotton per hour for each saw, and taking sixty as the number of the saws, 200 lbs. per hour will be the quantity cleaned, or, for eighteen hours' continuous working, from 7,000 to 7,500 lbs.

The average per cent. of cleaned cotton obtained from the seed-cotton of India is 20 to 25 per cent., while that of America is about 70 per cent. As our readers are doubtless aware, much attention is now being paid to the obtaining of our supplies of cotton from our Indian possessions, where almost any amount of cotton can be grown. One of the important points to be attended to in fostering the cotton-growing business in that country, is the introduction of improved machinery, whereby the utmost amount of cotton wool valuable for manufacturing purposes may be obtained from the produce. Some idea of the importance of attending to this department may be obtained from the statement, that 20 per cent. of the gross weight of cotton brought over to this country from India is dirt and rubbish, totally valueless. Now, it is quite evident that if this amount can be saved, or, what is the same thing, if the charges for freight consumed in paying for this valueless commodity can be disbursed in bringing over clean cotton, a large amount of saving must result. Hence the imperative demand that exists for the introduction of a superior class of cleaning machines into India.

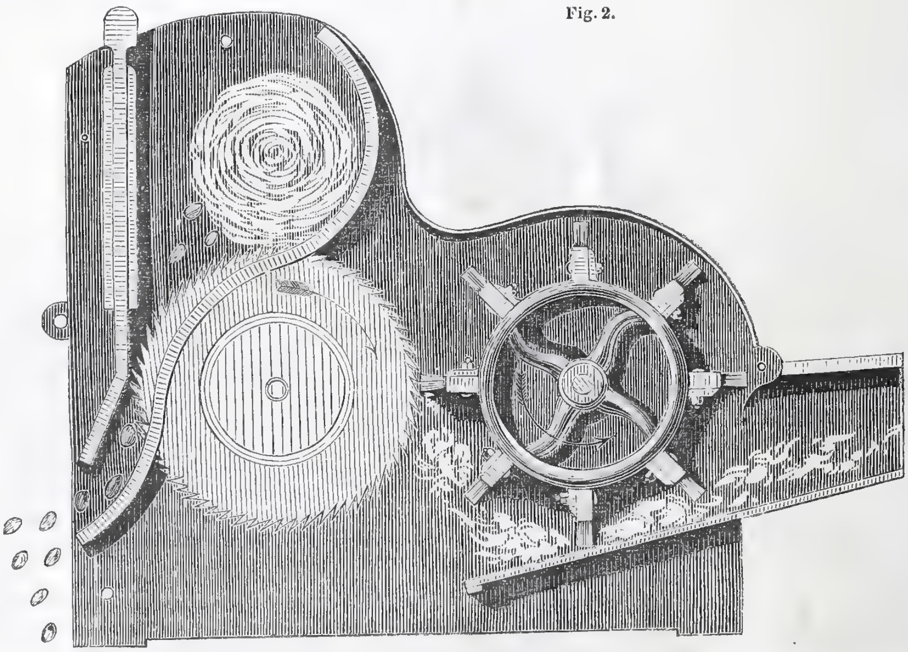
To the furtherance of this design, the Manchester Commercial Association have directed their efforts, and in conjunction with Mr. James Lees, a member of the Association, have introduced what is known as the Cottage Saw Gin, which is highly spoken of by competent authorities. It is portable, and is very much cheaper than the ordinary saw gin we have already described—being somewhere about one-twentieth of the cost of the British saw gin. Its entire weight is only about 80 lbs. Its use in India is rapidly progressing. The following table shows the comparative working economy of the three methods adopted in India for cleaning cotton, by which the superiority of the cottage gin is fully made evident:—

Machine.	Quantity of kappas cleaned per man per hour.	Price of cleaning per candy of 500 lbs.	Cost of tear and wear of machinery in every bale of cotton cleaned.
Cottage gin...	16 lbs.	Rupees, 2·17	1 6·16d.
Hand gin......	10·71 "	" 3·14	1 9·16d.
Churka.........	3 "	" 5	4·16d.

This table is that furnished by Mr. Fleming, Secretary of the Association. In fig. 1 we give a perspective elevation of the cottage saw gin, showing the method of working; and in fig. 2 a longitudinal section, showing the arrangement of saw and brush. In conjunction with our previous description of the "Whitney gin," the engravings will be sufficiently explicit.

We now proceed to describe and illustrate an important machine for separating the earthy and vegetable impurities from cotton, previous to being shipped from the country in which it is grown to this, the land of its manufacture. The machine to which we allude is that known as Hardacre's "Anglo-American Willow for India," "Normandy Cotton Opener," or the "Smut Cleaner;" and, although recently introduced, is fast coming into use. It is characterised by a practical cotton-spinner as a "first-rate machine for cleaning Surats." Its extended use in India—of course in a miniature size—is looked forward to by competent

Fig. 2.



judges as likely to do much for the cultivation of cotton for the home market. In the early periods of the history of the cotton manufacture in this country, the cotton was cleaned and opened by the process termed "batting." The cotton was opened in small quantities on an extended elastic network of cording, termed a flake, and beat with slender rods or wands—the extraneous substances in the cotton passing through the netting to a space below. So effectual is this process, that for "fine counts," that is, for the production of fine yarn for the lace manufacturer, it is still continued. It is, however, as may be supposed, a very tedious operation. The application of the principle, under more advantageous circumstances, so as to attain a high rate of speed without losing in efficiency, is that which is carried out in Hardacre's Cotton Opener. In

Fig. 3.

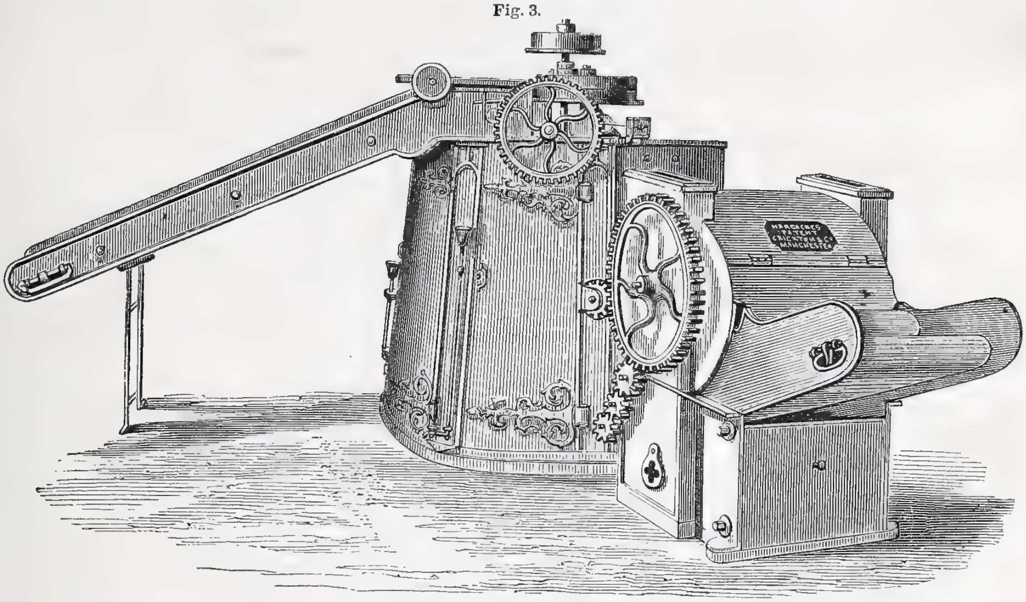
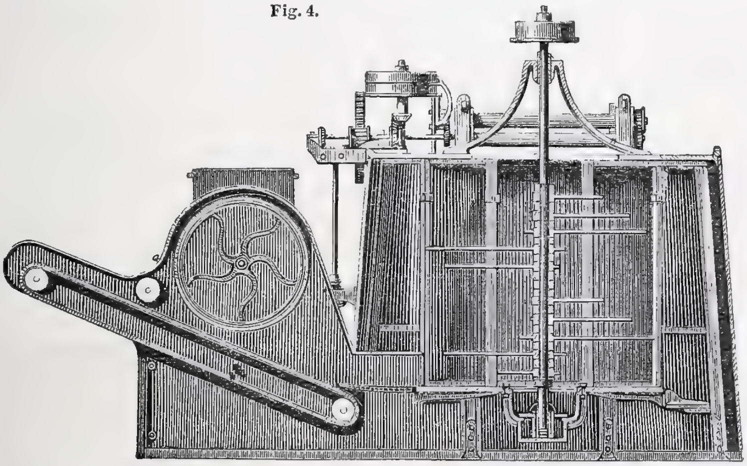


fig. 3 we give a perspective elevation of the machine; and in fig. 4 a section, showing the internal arrangements. These, in conjunction with the following description, will sufficiently explain its operation. To a vertical shaft, or shafts, a number of what may be called "batters" are fastened, projecting at right angles to the direction of its length. These batters are not placed so as to project irregularly from the shaft, that is, to be of irregular and unequal lengths; but are so arranged as to form, as it were, narrow steps, somewhat after the manner of the nosings of the steps of a geometrical staircase. The topmost pair of batters are furnished with projecting pins or teeth. The vertical shaft or shafts thus furnished with batters, revolve in a vertical cylindrical casing, the periphery of which is formed of narrow vertical strips of iron, placed angularly, so as to make one edge project inwards, and thus forming a series of edges, against which the cotton is forcibly driven by the revolving batters; the direction of the revolution of which, is the reverse of the angle of the iron vertical strips. Spaces are left between these strips, forming a species of vertical grating, through which the impurities ejected from the cotton are passed into spaces formed between the outer casing or covering and the vertical strips. The dirt is removed from these spaces by means of moveable doors or traps placed in the outer casing. The bottom of the interior casing is formed in like manner as the sides by narrow strips of iron, radiating from the centre, and placed angularly, so as to present a series of edges. The cotton to be cleaned is passed through an opening in the cover, and falls at once upon the upper pair of batters provided with the projecting teeth. Falling from series to series of batters, it is made to strike rapidly the edges of the inner case; the dirt being passed through to the spaces before described, the heaviest portion being expelled by the centrifugal force generated by the high rate of velocity at which the shaft revolves—from 700 to 1000 times per minute. The lighter portion is drawn off by a fan revolving at a high rate of speed—(not shown in the drawing.) The cotton, after being cleaned, passes up the inclined shoot, at the left hand of fig. 4, and is finally delivered into baskets or other receptacles in a light feathery condition. A machine on this principle, requiring one and a half horse power only, is calculated to clean effectually 40,000 lbs. of cotton in a week of 57½ hours. Such is the calculation of the patentee; but a practical authority, whose opinion is of value, states, that as the result of a personal inspection of several machines at work in various factories, it is much under the work, 60,000 lbs. per week being nearer the work done.

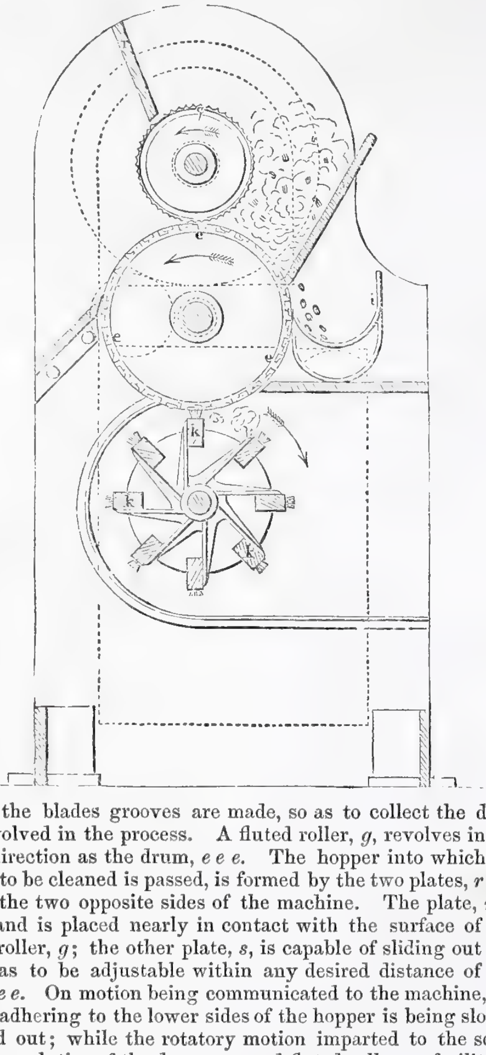
Fig. 4.



An improvement in the saw gin has been recently introduced by Mr. Calvert of Manchester, by which many of the disadvantages of the ordinary machine are obviated. From the nature of the latter, the cotton is subjected to a very violent operation, being torn or sawn asunder, and the quality of the cotton, or its "staple"—that is, the length and fineness of its fibre—much injured. Motes are also sometimes detached from the seeds by

the saw, which, mixing with the wool, entail after labour, before the cotton is fit for the purposes of manufacture; again, the extraneous matters contained among the cotton, such as stones, grit, &c., break the teeth, thus adding considerably to the expenses of its working, from necessitating frequent repairs. The principle of Mr. Calvert's machine is a "gentle combing out," rather than a "tearing asunder" of the fibres of the cotton. In fig. 5 we give a vertical section of this machine, showing the arrangement of the machinery. A drum, *e e e*, is furnished with a series of serrated or saw-edged steel blades;

Fig. 5.



under the blades grooves are made, so as to collect the dust, &c., evolved in the process. A fluted roller, *g*, revolves in the same direction as the drum, *e e e*. The hopper into which the cotton to be cleaned is passed, is formed by the two plates, *r* and *s*, and the two opposite sides of the machine. The plate, *r*, is fixed, and is placed nearly in contact with the surface of the fluted roller, *g*; the other plate, *s*, is capable of sliding out and in, so as to be adjustable within any desired distance of the drum, *e e*. On motion being communicated to the machine, the cotton adhering to the lower sides of the hopper is being slowly combed out; while the rotatory motion imparted to the seeds by the revolution of the drum, *e e*, and fluted roller, *g*, facilitates the process greatly, thus presenting every portion of the seeds to the action of the teeth of the drum, *e e*, till the whole of the fibre is stripped from them. The seeds drop through the space between the edge of the plate, *s*, and the periphery of the drum, *e e*, the cotton being stripped from the drum by the brush, *k k*, revolving in an opposite direction, and at an increased speed. The comb-plates being secured into the surface of the drum, *e e*, are not so liable to be broken off. The cotton cleaned by this machine is said to be worth fully one-fourth to one-half per lb. more than the saw-ginned.

"The importance," says a practical writer on the subject—one who has ably and perseveringly advocated the extension of our Indian cotton trade—"The importance of a speedy introduction of cleaning machinery into India can scarcely be over estimated. The secret regarding the rapid extension of the cotton cultivation in America lies in the early introduction and extensive use of her cleaning machinery. Without the saw gin, the southern States of America, notwithstanding their millions of slaves, would at the present moment be unable to find labour to clean their yearly crop of cotton. Whitney's invention has been to America, what Arkwright's has been to this country. The saw gin is now taking firm root in India; and the successful introduction of it there, may be looked upon as one of the most hopeful movements towards an improved quality, and an increased importation from that country." Some idea of the important connection which this machine has with the increase of the Indian trade, may be gathered from the following statement by Mr. Laird, of the influence it exerted on that of America. In 1770, the total quantity of export cotton grown in that country was seven bags and three barrels. From 1785 to 1790 inclusive, the amount exported was at the rate of 240 bales yearly. In 1791, this had only increased to 631. In 1793, the saw gin was introduced; such was its immediate influence, that, in the year following, the quantity exported was no less than 5,340 bales, or eight times that of the preceding year. In ten years after the introduction of this machine, the export had increased a hundredfold. In 1850, the number of bales was about 2,500,000. But not only is the operation of saw ginning infinitely quicker than roller ginning—the pecuniary advantage resulting from its use, from the higher price the cotton obtains in the market, is not the least point to be noted in comparing the two machines.

From the light feathery condition of the fibres of cotton wool, much space would be taken up in its conveyance by sea without pressure. To obviate this, and to lessen the charges of freight, a large mass of cotton is compressed by mechanical means, so as to take up little space. Trifling as this operation appears, yet, like every other branch of the cotton trade, it gives rise to a peculiar business of much commercial importance. One company in India alone has invested £20,000 in "presses" for executing this operation; and a large amount is invested in the business of packing cotton in the United States of America.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING.
THE CALOTYPE, DAGUERREOTYPE, &c.

CHAPTER VI.

THEORY OF THE DAGUERREOTYPE—SIMPLIFICATION OF THE PROCESS—PHOTOGRAPHY ON ALBUMINIZED GLASS PLATES.

It must be admitted that the theory of the daguerreotype process is still involved in considerable mystery. The following, however, appears to be the true explanation of the action of light, and the subsequent action of mercurial vapour, on the prepared surface. "On photographic papers," says Mr. Hunt, "the decomposed argentine salt exists in a state of oxide, mixed, in all probability, with some revived metal; but on the silver tablet the iodine is liberated from all the parts on which the light acts, and pure silver, in a state of extreme division, results. The depth to which the decomposition has been effected being in exact relation to the intensity and *colour* of the light radiated from the object which we desire to copy, the mercurial vapour unites with different proportions of silver, and thus are formed the lights and middle tints of the picture. The shadows are produced by the unchanged silver, from which the *ioduret* is removed by the hyposulphite of soda."

"It is probable," says M. Claudet, "that light exercises a twofold action on the iodide of silver, whether it is combined or not with chlorine or bromine. By one the iodide is decomposed, and the silver set free is precipitated on the surface, in the form of a white powder or small crystals; by the other action, which begins long before the former, the parts affected by light have been endowed with an affinity for mercurial vapour. By means of my photographometer, I have been able to ascertain that the pure light of the sun performs, in about two or three seconds, the decomposition of the bromo-iodide of silver, which is manifested by the white precipitate; while the

same intensity of light determines the affinity for mercurial vapour in the wonderfully short space of about $\frac{1}{1000}$th part of a second, so that the affinity for mercury is imparted by an intensity of light 3,000 times less than that which produces the decomposition manifested by the white precipitate."

The experiments of Mr. Shaw of Birmingham, and Dr Percy—the results of which were published in the Philosophical Magazine for December, 1844—have thrown much interesting light on the action of the iodine and bromine vapour on the tablets. From these experiments it appears, that if a prepared plate, after exposure to the light, be again submitted to the vapour of iodine or bromine, it is found that the vapour of mercury no longer attacks it, or, in other words, the impression produced by light is destroyed; but if it be again exposed to the light, after the second exposure to the mixed vapour, or to that of the iodine or bromine separately, and then submitted to the mercury vapour, the action of the light is developed.

It therefore appears that the impression produced by the light on a daguerreotype plate, prepared by exposure to the vapour of iodine and bromine, is wholly destroyed by a second exposure to the mixed vapours, and that, at the same time, its sensitiveness to light is restored. "So completely," says Mr. Shaw, "does the mixed vapour restore the sensitiveness of prepared plates after exposure to light, that the most beautiful impressions were obtained in the *camera obscura*, in two seconds, on plates which had previously been *four* times exposed to the direct light of the sun, and after each such exposure treated with the mixed vapour."

Another important fact elicited by these experiments is, that exposure to the mixed vapour, *during the period of its action*, has the power of *suspending* or *preventing* the simultaneous action of light on the plate. It was clearly and conclusively proved that "light is incapable of exerting any appreciable influence on daguerreotype plates, during the time they are receiving their coatings of iodine and bromine."

"In their practical application," continues Mr. Shaw, "these experiments show that all the care which has been taken to exclude light from daguerreotype plates, during their preparation, is unnecessary; that, so far from a dark room being essential to the operations of the daguerreotype artist, the light of day may be allowed to fall on the plate during the whole time of its preparation, and that it is only necessary to withdraw it, at the same moment, from the action of bromine and light, by sliding it from the bromine vessel into the dark box, in which it is carried to the *camera obscura;* and where, from the situation or otherwise, there is a difficulty in observing the colour of the plate during the process of iodizing, it may be removed from the iodine vessel, and its colour examined by the direct light of the sun, without risk or injury; for, when returned to the iodine or bromine vessel for a moment, the effect of light is wholly destroyed. But perhaps the most valuable practical application of these facts is in the use of the same plate for receiving several impressions. When, on taking the portrait or picture of any object, there is reason to suppose that the motion of the person or object has rendered the operation useless, it is not necessary to throw aside the plate on which the imperfect impression has been taken, and resort to the tedious process of cleaning and preparing another; it is only necessary to treat the plate in the manner already pointed out (namely, to restore it to the iodine and bromine vessels), and it is again equal, in every respect, to a newly-prepared plate; and this treatment may be repeated until, by the slow accumulation of too thick a film of iodide of silver, the plate no longer possesses the same degree of sensitiveness to light."

SIMPLIFICATION OF THE PROCESS.

We may conclude our remarks on the daguerreotype by calling attention to the fact, that although the details which we have given may appear, from their very minuteness, to be somewhat tedious and complex, the principles involved in the process are exceedingly simple, and the operator may, by a due attention to these, obtain satisfactory results with very inexpensive apparatus. On this subject we may here introduce the following apposite remarks from Professor Hunt's treatise:—

"The extreme expense of the apparatus and plates, as supplied by the patentee, induced me, in the very first stage of my experiments, to endeavour to construct for myself a set which should be equally as effective and less expensive.

"I was soon satisfied that all the arrangements might be much simplified, and that any one may have constructed for himself, for less than twenty shillings, a set of apparatus by which he shall be enabled to produce pictures equalling, in every respect, those procured with the set sold at twenty pounds.

"My apparatus consists of a deal box the size of my plates, and three inches deep, with a thin loose board in the bottom. This board is well saturated with the tincture of iodine; the spirit is allowed partially to evaporate, and then, being put in its place, the plate is adjusted at a proper height above it, varying the height according to the temperature—the box being closed, the operation is completed in about three minutes. Another deal box, having a glass in one side, and a bottom of sheet-iron, which is slightly concaved to contain mercury, with grooves upon which the plate may rest at proper angles, serves to mercurialize the plates. My camera, which I use for every photographic process, is described in a future chapter." [See Mr. Hunt's extemporaneous camera in Chapter III.] "It is sometimes convenient, particularly when travelling, to use a piece of amalgamated copper, which may be prepared, when wanted, by rubbing it with some nitrate of mercury The expense of the plates may be very much reduced: instead of using copper *plated* with silver, I would recommend the use of silvered copper, which every one can prepare for himself at a very small expense."

For silvering the copper, Mr. Hunt recommends that a well-planished copperplate of the required size (which may be purchased in a high state of preparation from the engravers), be polished first with pumicestone and water, then with snake-stone, and finally brought up to a mirror surface with either rottenstone or jeweller's rouge. Ample directions for polishing have already been given. The copperplate is then to be well rubbed with salt and water, and then with the silvering powder. "No kind answers better," says Mr. Hunt, "than that used by clockmakers to silver their dial-plates. It is composed of one part of well-washed chloride of silver, five parts of cream of tartar, and four parts of table salt. This powder must be kept in a dark vessel, and in a dry place. For a plate six inches by five, as much of this composition as can be taken upon a shilling is sufficient. It is to be laid on the centre of the copper, and the fingers being wetted, to be quickly rubbed over every part of the plate, adding occasionally a little damp salt. The copper being covered with the silvering, it is to be speedily well washed in water in which a little soda is dissolved; and as soon as the surface is of a fine silvery whiteness, it is to be dried with a very clean warm cloth. In this state the plates may be kept for use. The first process is to expose the plate to the heat of a spirit flame, until the silvered surface becomes of a well-defined golden-yellow colour; then, when the plate is cold, take a piece of cotton, dipped in very dilute nitric acid, and rub lightly over it until the white hue is restored, and dry it with very soft clean cloths. A weak solution of the hydriodate of potash, in which a small portion of iodine is dissolved, is now passed over the plate with a wide camel's-hair brush. The silver is thus converted, over its surface, into an ioduret of silver; and in this state it is exposed to light, which blackens it. When dry, it is to be again polished, either with dilute acid or a solution of carbonate of soda, and afterwards with dry cotton and the smallest possible portion of prepared chalk: by this means a surface of the highest polish is produced. The plate being thus prepared, we proceed in the manner before directed."

Copperplates may also be beautifully silvered by galvanic agency; and in this case the silver deposit being perfectly pure, the necessity for the heating process is removed. Information on this point will be found in our series of papers on the Electrotype.

PHOTOGRAPHY ON GLASS.

The comparative economy of glass plates, their smoothness of surface and perfect transparency, are properties which

highly recommend their use in photography, and since the discovery of the collodion process they have been extensively employed for taking portraits. Their cheapness, indeed, and the facility with which they are prepared, promise in no long time to render their use so general, as in some measure to supersede the daguerreotype. To Sir John Herschel, the scientific world is indebted for the first published account of their successful application to photographic purposes. This appeared in his paper "On the chemical action of the rays of the solar spectrum on preparations of silver and other substances," published in the Philosophical Transactions for 1840. An attempt was subsequently made to embrace the process in a patent; but the previous publication of Sir John Herschel's experiments on glass, in which the principle was clearly divulged, prevented the success of the application for this purpose. Mr. Talbot, indeed, patented the use of unglazed porcelain, but this material had little to recommend it as a substitute for paper on glass; and now that Mr. Talbot has resigned his patent rights, we believe it is as little likely as ever to come into general use.

The surface of the glass itself, being totally passive or inert as regards the action of light, is merely the smooth tablet or plate on which the sensitive substances are spread for receiving the photographic impression. In this respect it differs in some measure both from the silver plates and the paper employed in the processes which we have already described: the former presenting a surface which actually combines with the iodine or bromine to form the sensitive material; the latter readily imbibing the silver and other solutions, and likewise assisting the action of light, by affording the organic matter which is found to be highly important, if not essential to the process.

The difficulty, therefore, to be overcome with a view to the employment of glass plates in photography, was to discover a substance which, being evenly spread on the glass, might form a transparent absorbent surface, adhering strongly to the glass, and insoluble in the solutions used. Different substances have been proposed for this purpose, such as albumen, gelatine, collodion, starch, serum, &c., all of which have been employed with greater or less success; but hitherto the best effects have been produced with albumen or collodion, and therefore we shall chiefly confine ourselves to those processes in which these are employed to afford the necessary coating for receiving the sensitive materials. Let the reader observe that neither the albumen nor collodion are in themselves sensitive to light, but that they afford merely the requisite absorbent film or coating, while at the same time, by furnishing organic matter, they undoubtedly contribute or co-operate in producing the desired effect. We shall first describe the process for

ALBUMINIZED GLASS PLATES.

It is to the nephew of M. Niepce, of St. Victor, the distinguished colleague of M. Daguerre, that we owe the application of albumen to the art of photography on glass. The plates prepared with it are well suited for the reproduction of engravings, pictures, landscapes, sculpture, &c., but have not hitherto been rendered sufficiently sensitive to answer quite so well for portraits.

The process with albumen cannot be better described than in the words of Mr. Malone, whose experiments have been very successful:—

"To the white of an egg, its own bulk of water is to be added; the mixture, beaten with a fork, is then strained through a piece of linen cloth, and preserved for use in a glass-stoppered vessel; then a piece of plate glass, cleaned with a solution of caustic potash, or any other alkali, is to be washed with water, and dried with a cloth. When the glass is about to be used, breathe on it, and rub its surface with clean new blotting paper; then, to remove the dust and fibres which remain, use cotton-wool or a piece of new linen. Unless this latter, and, indeed, every other precaution is taken to prevent the presence of dust, the picture will be full of spots, produced by a greater absorption of iodine (in a subsequent process) in those than in the surrounding parts.

"On the clear glass pour the albumen, inclining the plate from side to side until it is covered; allow the excess to run off at one end of the corners, keeping the plate inclined, but nearly vertical. As soon as the albumen ceases to drop rapidly, breathe on or warm the lower half of the plate; the warmth and moisture of the breath will soon cause it to part with more of its albumen, which has now become more fluid: of course, care must be taken to warm only the lower half. Wiping the edges constantly, hastens the operation. Until this plan was adopted, the coatings were seldom uniform; the upper half of the plate retained less than the lower. When no more albumen runs down, dry the plate by a lamp, or by a common fire, if the dust that it is inclined to impart be avoided.

"The next operation is to iodize the plate. Dilute pure iodine with dry white sand in a mortar, using about equal parts of each; put this mixture into a square vessel, and place over it the albuminized plate, previously heated to about 100° Fahr. As soon as the film has become yellow in colour, resembling beautifully stained glass, remove the plate into a room lighted by a candle, or through any yellow transparent substance—yellow calico, for instance—and plunge it vertically and rapidly into a deep narrow vessel containing a solution of one hundred grains of nitrate of silver, to fifty minims of glacial acetic acid, diluted with five ounces of distilled water. Allow it to remain until the transparent yellow tint disappears, to be succeeded by a milky-looking film of iodide of silver. Washing with distilled water leaves the plate ready for the camera.

"It may be here noted, that the plate is heated in iodizing for the purpose of accelerating the absorption of the iodine: an exposure to the vapour for ten minutes, with a few seconds' immersion in the silver solution, has been found to be sufficient."

Along with the iodine, hydrochloric acid, chlorine or bromine may be used to increase the sensibility of the plate.

On removing the plate from the camera, a saturated solution of gallic acid is poured over it. "A negative talbotype image," continues Mr. Malone, "is the result. At this point previous experimentalists have stopped. We have gone further, and find that, by pouring upon the surface of the reddish-brown negative image, during its development, a strong solution of nitrate of silver, a remarkable effect is produced. The brown image deepens in intensity until it becomes black. Another change commences—the image begins to grow lighter; and finally, by perfect natural magic, black is converted into white, presenting the curious phenomena of the change of a talbotype *negative* into apparently a *positive* daguerreotype, the positive still retaining its negative properties when viewed by transmitted light."

The picture is fixed by pouring on the plate a solution of one part of hyposulphite of soda in sixteen parts of water, and leaving it for several minutes till the iodide of silver is dissolved. The process is then completed by washing in water.

The reader will observe the analogy between the talbotype or calotype, and this process with albumen. In the first place, a film of white of egg, or albumen, is deposited over the glass to form an absorbent surface. This surface is then iodized, and subsequently dipped into aceto-nitrate of silver, to form the iodide of silver—the substance which is sensitive to light. The negative picture is developed by gallic acid, and fixed with a solution of hyposulphite of soda. The most curious part of the process, however, is the production of a positive, by pouring nitrate of silver on the picture during the time of its development.

For producing negatives, the process may be simplified by iodizing the albumen before albuminizing the plate, so that the latter receives the albumen and the iodine at one operation. This is done by adding to the white of an egg (from which the white curds have been carefully removed by straining, or otherwise) ten drops of a saturated solution of iodide of potassium, and about two drachms of water, heating up the mixture to a white froth, and then leaving it to stand for six or eight hours until it becomes a clear solution.

M. Le Gray recommends the following mixture. Put into a large basin the whites of ten eggs, very fresh, and dissolve in the liquid:—

Iodide of potassium............	1 drachm.
Bromide of potassium..........	$7\frac{1}{2}$ grains.
Chloride of sodium............	$7\frac{1}{2}$ grains.

Beat this mixture in a large dish with a wooden fork, until it is reduced to a white froth, then let it repose all night; the next day decant the viscous liquid which has deposed, and use it for the preparation of your glasses.

M. Le Gray recommends thin glass, or, "what is much better, *ground glass, on which the adherence is more perfect.*" After applying the prepared albumen, the plate is carefully dried, and then dipped by an "instantaneous and regular immersion" in a bath of aceto-nitrate of silver. "This operation," says M. Le Gray, "is very delicate, because the least stoppage in its immersion in the bath will operate on the sensitive coating, and cause irregularities which nothing can remedy. The plate is left to soak two or three minutes in the bath, then withdrawn and washed perfectly with distilled water, after which it is left in a dark place to dry. Thus prepared, the glasses may be kept one or two days (in perfect exclusion from light) before being exposed in the camera. The image is developed, "as that of negatives on paper, by putting it into a warm bath of gallic acid, containing, at most, one-tenth in volume of aceto-nitrate of silver. It requires one or two hours, or even more, to develop the image." It is then fixed with hyposulphite of soda.

We shall describe in next chapter the processes on glass with collodion.

THEORY AND PRACTICE OF NAVIGATION.

The science of Navigation is based on mathematical principles and astronomical observations, so that, by rules founded on these, the mariner is enabled to conduct his ship on the pathless ocean, with almost unerring precision, from one point of the globe to another.

The art of Navigation must have been practised at a very remote epoch in human history; but in the earlier ages of the world, as among the savage tribes of the present day, the boldest voyages must have been limited to islands at no great distance from the continent. Astronomy was one of the earliest studies of mankind; and the motions and relative position of the heavenly bodies would soon attract the attention of the mariner who dared, for the first time, to launch his adventurous bark on more extensive excursions. But the constant aim of the earliest navigators was to creep cautiously along in sight of land, with the bearings of which they were acquainted. The heavenly bodies were their last resource, when overtaken by storms and drifted to sea; and, such contingencies frequently occurring, would lead to the dispersion of the human family, by peopling remote islands and continents. Prior to the discovery of the mariner's compass, distant voyages were seldom attempted; and must have been attended, when undertaken, with great uncertainty and hazard.

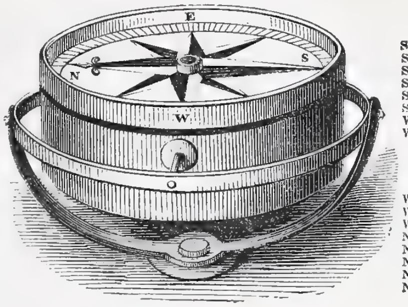
The invention or discovery of the mariner's compass is claimed by almost every civilized nation; but its introduction into Europe is supposed to have been due to the Arabs in the 12th century, or about the time of the Crusades. At the same time, there is evidence to prove that the Chinese used the compass hundreds of years before its introduction into Europe. This is by far the most important nautical instrument, for by it the mariner is enabled to pursue his way on the pathless ocean; while, by means of his quadrant, he ascertains his position with reference to the sun, moon, and stars.

THE MARINER'S COMPASS.

The Mariner's Compass is a representation of the horizon of any plane. The construction is as follows:—There is a circular card, a portion of which will be observed in the annexed engraving; the card is divided into 32 equal points, and the lines drawn from the centre to the circumference are called *rhumb lines*, these lines terminating at the points. Each point is equal to 11° 15′. The four principal points are called *Cardinal Points*, and are named *North, South, East*, and *West*. The other points are compounds or combinations of these, according to their position on the card. To the under side of the card, on the north and south line, is fixed a magnetic bar, made of steel, and hardened, the needle being magnetized by a battery or touched by a loadstone. The card and needle are then suspended on a centre, which is fixed to the bottom of a brass or wooden bowl. The whole is covered with a plate of glass, to prevent the wind from disturbing the card; and the box itself is then suspended within a ring, and fixed to two points, which act as centres, so

	°	′
N.	0	0
N by E	11	15
NNE	22	30
NEbyN	33	45
NE	45	0
NEbyE	56	15
ENE	67	30
E by N	78	45

	°	′
E.	90	0
E by S	78	45
ESE	67	30
SEbyE	56	5
SE	45	0
SEbyS	33	45
SSE	22	30
S by E	11	15



	°	′
S.	0	0
S by W	11	15
SSW	22	30
SWbyS	33	45
SW	45	0
SWbyW	54	5
WSW	67	30
W by S	78	45

	°	′
W.	90	0
W by N	78	45
WNW	67	30
NWbyW	56	15
NW	45	0
NWbyN	33	45
NNW	22	30
N by W	11	15

that the compass moves freely within it. When the apparatus is thus arranged, the needle points north and south, and follows the magnetic meridian in whatever position it may be placed, except when influenced by iron or magnetized bodies.

In the inside of the circular box is drawn a black line, vertically, which line is called the *lubber's point*. The compass is then placed in the binnacle, and the line joining the centre of the card and lubber's point must be made parallel to the ship's keel, so that whatever course the ship assumes will be indicated by the card. Many improvements have been made in the mechanical construction of the Mariner's Compass, in order to give steadiness to the magnetic needle, as its oscillations are great when under the influence of winds and currents, the ship being made to heave much under these circumstances; these improvements will be referred to when we come to treat of amplitudes and azimuths.

THE LOG-LINE AND HALF-MINUTE GLASS.

The Log-line is generally 100 or 150 fathoms in length, and is divided into equal parts, called knots. Each knot is marked by a distinct colour, and is generally divided into 8 fathoms of 6 feet each, or 10 fathoms of 5 feet each.

The half-minute glass is of the same form as the common sand-glass, and should run out in 30 seconds. The form is so generally known that it needs no explanation.

QUADRANT OR SEXTANT.

Hadley's Quadrant or Sextant is an instrument of prime importance for observing the altitude of celestial bodies at sea. The form of the quadrant is the 8th part of a circle, or 45°; but from the double reflection of the glasses, the arch is divided into 90°. By this instrument the mariner is enabled to find his latitude and longitude, by observations made from the sun, moon, and stars.

These instruments, with the addition of a few charts and a good chronometer, constitute the principal apparatus used at sea.

DEFINITIONS OF THE SPHERE.

The phenomena of day and night arise from the diurnal motion of the earth on its axis, from west to east, in twenty-four hours.

The axis is an imaginary line passing through the centre of the earth.

The extremities of this line are called the North and South Poles; that towards the north is called the North Pole, and its opposite the South Pole. The axis of the earth, if produced to the stars, would pass through the celestial poles.

The Equator is a great circle on the earth, every point of which is equally distant from the poles. It divides the earth into two equal parts, called Hemispheres; that having the north pole in its centre is called the Northern Hemisphere, and the other the Southern Hemisphere. The plane of this circle,

if supposed to be produced to the fixed stars, will mark out the celestial equator or equinoctial.

The equator is divided into 360 equal parts, called Degrees; each degree is divided into 60 equal parts, called Minutes; and each minute into 60 equal parts, called Seconds, marked thus: —50° 40′ 30″.

Meridians are great circles passing through both the poles, cutting the equator at right angles, and dividing the globe into two parts, called the Eastern and Western Hemispheres. Each nation has its fixed meridian passing through some remarkable place, and this, with reference to that nation, is called the first meridian.

In Britain, the first meridian is that which passes through the Royal Observatory at Greenwich.

The Latitude of any place is a point on its meridian, either north or south of the equator, according to its position.

Parallels of Latitude are circles parallel to the equator, and form right angles with the meridian lines. Hence it is evident that the difference of latitude between any two places, is an arch of a meridian contained between the two places. If both places be on the same side of the equator, their difference of latitude is found by subtracting the less latitude from the greater; but if they be on opposite sides of the equator, their difference of latitude is equal to the sum of the latitudes of both places. Latitude is measured from the equator towards the poles, and cannot exceed 90°, that being the distance of the poles from the equator.

The Longitude of any place is that portion of the equator which is contained between the first meridian and the meridian of the given place. The longitude of a place is said to be either east or west, according as the place is on the east or west side of the first meridian, and cannot exceed 180°.

The Difference of Longitude between any two places, is that portion of the equator which is intercepted between the meridians of these places.

To find the Difference of Latitude between two places.

Rule.—When the latitudes are both north or both south, subtract the less latitude from the greater, the remainder will be the difference of latitude; but when one is north and the other south, their sum gives the difference of latitude.

Example 1.—What is the difference of latitude between Glasgow and Lisbon?

Latitude of Glasgow, . . .	55° 51′ N.
Latitude of Lisbon, . . .	38° 42′ N. subtract.
Difference of latitude, . . .	17° 9′
	60
In miles, ...	1029

Example 2.—What is the difference of latitude between London and St. Helena?

Latitude of London, . . .	51° 30′ N.
Latitude of St. Helena, . . .	15° 54′ S. add.
Difference of latitude, . . .	67° 24′
	60
In miles, ...	4044

Given the Latitude sailed from, and Difference of Latitude, to find the Latitude come to.

Rule.— When the latitude left and difference of latitude are of the same name, add them together—their sum gives the latitude come to; but when the one is north and the other south, subtract the less from the greater—the remainder gives the latitude of the ship, of the same name as the greater.

Example 1.—A ship from latitude 38° 50′ N., sails northward until her difference of latitude is 780 miles.—What is the latitude come to?

Latitude left, ...	38° 50′ N.
Difference of latitude, 780 miles, or .	13° 0′ N. add.
Latitude come to, ...	51° 50′ N.

Example 2.—A ship sails 1000 miles southerly from latitude 12° 36′ N.—What is the latitude come to?

Latitude left, ...	12° 36′ N. subtract.
Difference of latitude, 1000 miles, or	16° 40′ S.
Latitude come to, ...	4° 4′ S.

In the example last given, it will be seen that the difference of latitude is greater than the latitude left, the ship having crossed the equator, and is in south latitude.

To find the Difference of Longitude between two places.

Rule.—If the longitudes of the given places be both east or both west, subtract the less from the greater; but if one be east and the other west, add them together; the sum will be the difference of longitude. If the sum of the two longitudes exceed 180°, subtract it from 360°; the remainder will be the difference of longitude.

Example 1.—What is the difference of longitude between Liverpool and Londonderry?

Longitude of Londonderry, . .	7° 20′ W.
Longitude of Liverpool, . .	2° 58′ W. subtract.
Difference of longitude, . . .	4° 22′
	60
In miles, ...	262

Example 2.—A ship sails from Canton till she arrives at longitude 160° W.—What is her difference of longitude?

Longitude of Canton, . . .	113° 14′ E.
Longitude of ship, ...	160° 0′ W. add.
Sum, ...	273° 14′ subtract.
	360° 0′
Difference of longitude, . . .	86° 46′
	60
In miles, ...	5206

Given the Longitude left, and the Difference of Longitude, to find the Longitude come to.

Rule.—If the longitude left and difference of longitude be of different names, subtract the less from the greater, and the remainder will be the longitude come to of the same name as the greater; but if the longitude left and difference of longitude be of the same name, their sum will be the longitude come to of the same name as the longitude left; if this sum exceed 180°, subtract it from 360°, and the remainder will be the longitude come to of a different name to the longitude left.

Example 1.—A ship sailed west from longitude 146° 36′ W. until her difference of longitude was 12° 30′ W.—What is her present longitude?

Longitude left, . . .	146° 36′ W.
Difference of longitude, . . .	12° 30′ W. add.
Present longitude, ...	159° 6′ W.

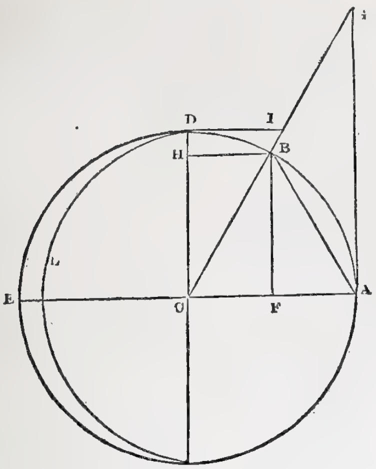
Example 2.—A ship sails eastward from the island of Otaheite, in the South Sea, until her difference of longitude is 500 miles.—What is the longitude come to?

Longitude of Otaheite, . . .	149° 28′ W.
Difference of longitude, 500 miles, or	8° 20′ E. subtract.
Longitude come to, ...	141° 8′ W.

Example 3.—A ship, from longitude 174° 36′ W., sailed westward, until her difference of longitude was 12° 20′ W.—What is the longitude come to?

Longitude left, ...	174° 36′ W.
Difference of longitude, . . .	12° 20′ W. add.
Sum, ...	186° 56′ subtract.
	360° 0′
Longitude come to, ...	173° 4′ E.

The circumference of every circle is divided into 360 equal parts, called degrees; each degree is divided into 60 equal parts, called minutes; and each minute into 60 equal parts, called seconds.



Any part of a circle is called an arch, and its measure is expressed in degrees and parts of a degree.

The chord of an arc is a straight line joining its extremities. Let A B be an arc, then the line A B joining its extremities is the chord of that arc.

The sine of an arc is a straight line, as B F is the sine of the arc, A B, or angle, A C B.

The versed sine of the arc, A B, is A F.

The tangent of the arc, A B, is A G. The secant of the arc, A B, is C G. A quadrant is one-fourth part of a circle, and contains 90 degrees, as A D C.

The complement of an arc is what it wants of a quadrant, or 90°; thus, D B is the complement of B A, or B A is the complement of B D.

The supplement of an arc is what it wants of a semicircle, or 180°; thus, E B is the supplement of B A, or B A is the supplement of E B.

The sine, versed sine, tangent, and secant of the complement of an arc, are called the co-sine, co-versed sine, co-tangent, and co-secant of that arc; thus, B H is the co-sine, D H the co-versed sine, D I the co-tangent, and C I the co-secant of the arc, A B.

The sine, tangent, and secant of an arc, are also the sine, tangent, and secant of the supplement of that arc; thus, B F is the sine of the arcs, A B and B E; and A G is the tangent and C G the secant of these arcs.

LOGARITHMS.

The various questions in navigation are in general solved by Logarithms, which are a series of artificial numbers, so arranged as to correspond to a set of natural numbers, in such a way that the sum of the logarithms of any two numbers is the logarithm of the product of these numbers; so that, by logarithms, multiplication is performed by addition, and division by subtraction.

If we assume the following geometrical series as natural numbers, ... 1, 10, 100, 1000, 10000, and the arithmetical series as their logarithms, . . . 0, 1, 2, 3, 4, then it is evident that the log. of 1 is 0, the log. of 10 is 1, the log. of 100 is 2, the log. of 1000 is 3, &c. From these arrangements, it is plain that the log. of a number less than 10 will be a fraction; the log of a number above 10, and less than 100, will be 1 and a fraction; the log. of a number between 100 and 1000 will be 2 and a fraction, &c. The above series are called common logarithms, to distinguish them from other forms of logarithms. From the above, it will be evident that that part of a logarithm which forms the whole number, and is called the index, is always one less than the number of figures in the natural number, independent of fractions, if there be any in that number. This rule is so easy of application, that the indices of logarithms are never printed in the tables, but are left to be supplied by the person using them. The index descends in the same proportion as it ascends; but need not be treated of here, as not being required in the general practice of navigation.

To find the Logarithm of any given number.

Example 1.—Find the logarithm of 6.

Turn to the table, and opposite the given number is found 0·778151; the given number being less than 10, its log. must be a number less than 1, and of course has no index.

Example 2.—Find the logarithm of 75.

Turn to the table, and opposite 75 is found 1·875061; the given number consisting of two figures (a whole number), its index is 1.

Example 3.—Find the logarithm of 338.

Opposite the given number in the table is the corresponding logarithm, 2·528916; the given number being a whole number, and consisting of three figures, its index must be 2.

Example 4.—Required the logarithm of 86·5.

When the given number contains a fraction, find in the table the logarithm corresponding to the given number, as if it were a whole number, but make the index to agree with the whole part of the given number; in this example, the logarithm is 1·937016.

To find the Natural Number corresponding to a given Logarithm.

Example 1.—Find the natural number corresponding to the logarithm 2·523746.

Look in the table for the nearest number to the decimal part of the given logarithm, and in the left-hand column is found 334, the natural number; the index being 2, the natural number must consist of three figures, a whole number.

Example 2.—What is the natural number for the logarithm 1·755874?

Look in the table for the nearest number to the decimal part of the logarithm, and in the left-hand column is found 57; the index being 1, the answer will be two figures, a whole number.

TABLE I.

LOGARITHMS OF NUMBERS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
1	0·000000	11	1 041393	21	1·322219	31	1·491362	41	1·612784	51	1·707570	61	1·785330	71	1·851258	81	1·908485	91	1·959041
2	0·301030	12	1·079181	22	1·342423	32	1·505150	42	1·623249	52	1·716003	62	1·792392	72	1·857332	82	1·913814	92	1·963788
3	0·477121	13	1·113943	23	1·361728	33	1·518514	43	1·633468	53	1·724276	63	1·799341	73	1·863323	83	1·919078	93	1·968483
4	0·602060	14	1·146128	24	1·380211	34	1·531479	44	1·643453	54	1·732394	64	1·806180	74	1·869232	84	1·924279	94	1·973128
5	0·698970	15	1·176091	25	1·397940	35	1·544068	45	1·653213	55	1·740363	65	1·812913	75	1·875061	85	1·929419	95	1·977724
6	0·778151	16	1·204120	26	1·414973	36	1·556302	46	1·662758	56	1·748188	66	1·819544	76	1·880814	86	1·934498	96	1·982271
7	0·845098	17	1·230449	27	1·431364	37	1·568202	47	1·672098	57	1·755875	67	1·826075	77	1·886491	87	1·939519	97	1·986772
8	0·903090	18	1·255273	28	1·447158	38	1·579784	48	1·681241	58	1·763428	68	1·832509	78	1·892095	88	1·944483	98	1·991226
9	0·954243	19	1·278754	29	1·462398	39	1·591065	49	1·690196	59	1·770852	69	1·838849	79	1·897627	89	1·949390	99	1·995635
10	1·000000	20	1·301030	30	1·477121	40	1·602000	50	1·698970	60	1·778151	70	1·845098	80	1·903090	90	1·954243	100	2·000000

TABLE I.—(*Continued.*)

LOGARITHMS OF NUMBERS.

No.	0	No.	0	No.	0	No.	0	No.	0	No.	0	No.	0	No.	0	No.	0	No.	0
100	000000	190	278754	280	447158	370	568202	460	662758	550	740363	640	806180	730	863323	820	913814	910	959041
101	004321	191	281033	281	448706	371	569374	461	663701	551	741152	641	806858	731	863917	821	914343	911	959518
102	008600	192	283301	282	450249	372	570543	462	664642	552	741939	642	807535	732	864511	822	914872	912	959995
103	012837	193	285557	283	451786	373	571709	463	665581	553	742725	643	808211	733	865104	823	915400	913	960471
104	017033	194	287802	284	453318	374	572872	464	666518	554	743510	644	808886	734	865696	824	915927	914	960946
105	021189	195	290035	285	454845	375	574031	465	667453	555	744293	645	809560	735	866287	825	916454	915	961421
106	025306	196	292256	286	456366	376	575188	466	668386	556	745075	646	810233	736	866878	826	916980	916	961895
107	029384	197	294466	287	457882	377	576341	467	669317	557	745855	647	810904	737	867467	827	917505	917	962369
108	033424	198	296665	288	459392	378	577492	468	670246	558	746634	648	811575	738	868056	828	918030	918	962843
109	037426	199	298853	289	460898	379	578639	469	671173	559	747412	649	812245	739	868644	829	918555	919	963315
110	041393	200	301030	290	462398	380	579784	470	672098	560	748188	650	812913	740	869232	830	919078	920	963788
111	045323	201	303196	291	463893	381	580925	471	673021	561	748963	651	813581	741	869818	831	919601	921	964260
112	049218	202	305351	292	465383	382	582063	472	673942	562	749736	652	814248	742	870404	832	920123	922	964731
113	053078	203	307496	293	466868	383	583199	473	674861	563	750508	653	814913	743	870989	833	920645	923	965202
114	056905	204	309630	294	468347	384	584331	474	675778	564	751279	654	815578	744	871573	834	921166	924	965672
115	060698	205	311754	295	469822	385	585461	475	676694	565	752048	655	816241	745	872156	835	921686	925	966142
116	064458	206	313867	296	471292	386	586587	476	677607	566	752816	656	816904	746	872739	836	922206	926	966611
117	068186	207	315970	297	472756	387	587711	477	678518	567	753583	657	817565	747	873321	837	922725	927	967080
118	071882	208	318063	298	474216	388	588832	478	679428	568	754348	658	818226	748	873902	838	923244	928	967548
119	075547	209	320146	299	475671	389	589950	479	680335	569	755112	659	818885	749	874482	839	923762	929	968016
120	079181	210	322219	300	477121	390	591065	480	681241	570	755875	660	819544	750	875061	840	924279	930	968483
121	082785	211	324282	301	478566	391	592177	481	682145	571	756636	661	820201	751	875640	841	924796	931	968950
122	086360	212	326336	302	480007	392	593286	482	683047	572	757396	662	820858	752	876218	842	925312	932	969416
123	089905	213	328380	303	481443	393	594393	483	683947	573	758155	663	821514	753	876795	843	925828	933	969882
124	093422	214	330414	305	482874	394	595496	484	684845	574	758912	664	822168	754	877371	844	926342	934	970347
125	096910	215	332438	305	484300	395	596597	485	685742	575	759668	665	822822	755	877947	845	926857	935	970812
126	100370	216	334454	306	485721	396	597695	486	686636	576	760422	666	823474	756	878522	846	927370	936	971276
127	103804	217	336460	307	487138	397	598790	487	687529	577	761176	667	824126	757	879096	847	927883	937	971740
128	107210	218	338456	308	488551	398	599883	488	688420	578	761928	668	824776	758	879669	848	928396	938	972203
129	110590	219	340444	309	489958	399	600973	489	689309	579	762679	669	825426	759	880242	849	928908	939	972666
130	113943	220	342423	310	491362	400	602060	490	690196	580	763428	670	826075	760	880814	850	929419	940	973128
131	117271	221	344392	311	492760	401	603144	491	691081	581	764176	671	826723	761	881385	851	929930	941	973590
132	120574	222	346353	312	494155	402	604226	492	691965	582	764923	672	827369	762	881955	852	930440	942	974051
133	123852	223	348305	313	495544	403	605305	493	692847	583	765669	673	828015	763	882524	853	930949	943	974512
134	127105	224	350248	314	496930	404	606381	494	693727	584	766413	674	828660	764	883093	854	931458	944	974972
135	130334	225	352182	315	498311	405	607455	495	694605	585	767156	675	829304	765	883661	855	931966	945	975432
136	133539	226	354108	316	499687	406	608526	496	695482	586	767898	676	829947	766	884229	856	932474	946	975891
137	136721	227	356026	317	501059	407	609594	497	696356	587	768638	677	830589	767	884795	857	932981	947	976350
138	139879	228	357935	318	502427	408	610660	498	697229	588	769377	678	831230	768	885361	858	933487	948	976808
139	143015	229	359835	319	503791	409	611723	499	698100	589	770115	679	831870	769	885926	859	933993	949	977266
140	146128	230	361728	320	505150	410	612784	500	698970	590	770852	680	832509	770	886491	860	934498	950	977724
141	149219	231	363612	321	506505	411	613842	501	699838	591	771587	681	833147	771	887054	861	935003	951	978180
142	152288	232	365488	322	507856	412	614897	552	700704	592	772322	682	833784	772	887617	862	935507	952	978637
143	155336	233	367356	323	509202	413	615950	503	701568	593	773055	683	834421	773	888179	863	936011	953	979093
144	158362	234	369216	324	510545	414	617000	504	702430	594	773786	684	835056	774	888741	864	936514	954	979548
145	161368	235	371068	325	511883	415	618048	505	703291	595	774517	685	835691	775	889302	865	937016	955	980003
146	164353	236	372912	326	513218	416	619093	506	704150	596	775246	686	836324	776	889862	866	937518	956	980458
147	167317	237	374748	327	514548	417	620136	507	705008	597	775974	687	836957	777	890421	867	938019	957	980912
148	170262	238	376577	328	515874	418	621176	508	705864	598	776701	688	837588	778	890980	868	938520	958	981365
149	173186	239	378398	329	517196	419	622214	509	706718	599	777427	689	838219	779	891537	869	939020	959	981819
150	176091	240	380211	330	518514	420	623249	510	707570	600	778151	690	838849	780	892095	870	939519	960	982271
151	178977	241	382017	331	519828	421	624282	511	708421	601	778874	691	839478	781	892651	871	940018	961	982723
152	181844	242	383815	332	521138	422	625312	512	709270	602	779596	692	840106	782	893207	872	940516	962	983175
153	184691	243	385606	333	522444	423	626340	513	710117	603	780317	693	840733	783	893762	873	941014	963	9836 6
154	187521	244	387390	334	523746	424	627366	514	710963	604	781037	694	841359	784	894316	874	941511	964	984077
155	190332	245	389166	335	525045	425	628389	515	711807	605	781755	695	841985	785	894870	875	942008	965	984527
156	193125	246	390935	336	526339	426	629410	516	712650	606	782473	696	842609	786	895423	876	942504	966	984977
157	195900	247	392697	337	527630	427	630428	517	713490	607	783189	697	843233	787	895975	877	943000	967	985426
158	198657	248	394452	338	528917	428	631444	518	714330	608	783904	698	843855	788	896526	878	943494	968	985875
159	201397	249	396199	339	530200	429	632457	519	715167	609	784617	699	844477	789	897077	879	943989	969	986324
160	204120	250	397940	340	531479	430	633468	520	716003	610	785330	700	845098	790	897627	880	944483	970	986772
161	206826	251	399674	341	532754	431	634477	521	716838	611	786041	701	845718	791	898176	881	944976	971	987219
162	209515	252	401400	342	534026	432	635484	522	717671	612	786751	702	846337	792	898725	882	945469	972	987666
163	212188	253	403120	343	535294	433	636488	523	718502	613	787460	703	846955	793	899273	883	945961	973	988113
164	214844	254	404834	344	536558	434	637490	524	719331	614	788168	704	847573	794	899820	884	946452	974	988559
165	217484	255	406540	345	537819	435	638489	525	720159	615	788875	705	848189	795	900367	885	946943	975	989005
166	220108	256	408240	346	539076	436	639486	526	720986	616	789581	706	848805	796	900913	886	947434	976	989450
167	222716	257	409933	347	540329	437	640481	527	721811	617	790285	707	849419	797	901458	887	947924	977	989895
168	225309	258	411620	348	541579	438	641474	528	722634	618	790988	708	850033	798	902003	888	948413	978	990339
169	227887	259	413300	319	542825	439	642464	529	723456	619	791691	709	850646	799	902547	889	948902	979	990783
170	230449	260	414973	350	544068	440	643453	530	724276	620	792392	710	851258	800	903090	890	949390	980	991226
171	232996	261	416640	351	545307	441	644439	531	725095	621	793092	711	851870	801	903632	891	949878	981	991669
172	235528	262	418301	352	546543	442	645422	532	725912	622	793790	712	852480	802	904174	892	950365	982	992111
173	238046	263	419956	353	547775	443	646404	533	726727	623	794488	713	853090	803	904715	893	950851	983	992553
174	240549	264	421604	354	549003	444	647383	534	727541	624	795185	714	853698	804	905256	894	951337	984	992995
175	243038	265	423246	355	550228	445	648360	535	728354	625	795880	715	854306	805	905796	895	951823	985	993436
176	245513	266	424882	356	551450	446	649335	536	729165	626	796574	716	854913	806	906335	896	952308	986	993877
177	247973	267	426511	357	552668	447	650307	537	729974	627	797268	717	855519	807	906873	897	952792	987	994317
178	250420	268	428135	358	553883	448	651278	538	730782	628	797960	718	856124	808	907411	898	953276	988	994757
179	252853	269	429752	359	555094	449	652246	539	731589	629	798651	719	856729	809	907948	899	953760	989	995196
180	255273	270	431364	360	556302	450	653213	540	732394	630	799341	720	857332	810	908485	900	954242	990	995635
181	257679	271	432969	361	557507	451	654176	541	733197	631	800029	721	857935	811	909021	901	954725	991	996074
182	260071	272	434569	362	558709	452	655138	542	733999	632	800717	722	858537	812	909556	902	955206	992	996512
183	262451	273	436163	363	559907	453	656098	543	734800	633	801404	723	859138	813	910090	903	955688	993	996949
184	264818	274	437751	364	561101	454	657056	544	735599	634	802089	724	859739	814	910624	904	956168	994	997386
185	267172	275	439333	365	562293	455	658011	545	736396	635	802774	725	860338	815	911158	905	956649	995	997823
186	269513	276	440909	366	563481	456	658965	546	737193	636	803457	726	860937	816	911690	906	957128	996	998259
187	271842	277	442480	367	564666	457	659916	547	737987	637	804139	727	861534	817	912222	907	957607	997	998695
188	274158	278	444045	368	565848	458	660865	548	738781	638	804821	728	862131	818	912753	908	958086	998	999130
189	276462	279	445604	369	567026	459	661813	549	739572	639	805501	729	862728	819	913284	909	958564	999	999565
	0		0		0		0		0		0		0		0		0		0

TABLE II.

Logarithmic Sines, Tangents, and Secants, to every Point and Quarter Point of the Compass.

Points.	Sine.	Cosine.	Tangent.	Cotangent.	Secant.	Cosecant.	Pnts.
0 0	0·00000	10·00000	0·00000	Infinite.	10·00000	Infinite.	8
0 ¼	8·69080	9·99948	8·69132	11·30868	10·00052	11·30920	7 ¾
0 ½	8·99130	9·99790	8·99340	11·00660	10·00210	11·00870	7 ½
0 ¾	9·16652	9·99527	9·17125	10·82875	10·00473	10·83348	7 ¼
1 0	9·29024	9·99157	9·29866	10·70134	10·00843	10·70976	7 0
1 ¼	9·38557	9·98679	9·39878	10·60122	10·01321	10·61443	6 ¾
1 ½	9·46282	9·98088	9·48194	10·51806	10·01912	10·53718	6 ½
1 ¾	9·52749	9·97384	9·55365	10·44635	10·02616	10·47251	6 ¼
2 0	9·58284	9·96562	9·61722	10·38278	10·03438	10·41716	6 0
2 ¼	9·63099	9·95616	9·67483	10·32517	10·04384	10·36901	5 ¾
2 ½	9·67339	9·94543	9·72796	10·27204	10·05457	10·32661	5 ½
2 ¾	9·71105	9·93335	9·77770	10·22230	10·06665	10·28895	5 ¼
3 0	9·74474	9·91985	9·82489	10·17511	10·08015	10·25526	5 0
3 ¼	9·77503	9·90483	9·87020	10·12980	10·09517	10·22497	4 ¾
3 ½	9·80236	9·88819	9·91417	10·08583	10·11181	10·19764	4 ½
3 ¾	9·82708	9·86979	9·95729	10·04271	10·13021	10·17292	4 ¼
4 0	9·84949	9·84949	10·00000	10·00000	10·15051	10·15051	4 0
	Cosine.	Sine.	Cotangent.	Tangent.	Cosecant.	Secant.	

To perform Multiplication by Logarithms.

RULE.—Add the logarithms of the factors, and the sum will be the logarithm of the product.

Example 1.—Multiply 162 by 3.

Factors { 162......... log. .... 2·209515
3......... log. .... 0·477121

Product, . 486 — 2·686636 sum of log.

Example 2.—Multiply 38 by 26.

Factors { 38......... log. .... 1·579783
26......... log. .... 1·414973

Product, . 988 — 2·994756 sum of log.

Example 3.—Multiply 368 by 22·5.

Factors { 368 .... log. .... 2·565848
22·5......... log. .... 1·352182

Product, 8280 — 3·918030 sum of log.

The last example given refers to those questions which have decimals as part of their factors; 368, the first factor, being a whole number of three figures, it must have for its index 2; the second factor, 22·5, being composed of a whole number and a decimal, the index of which must be one, as the whole part of the factor is 22. In finding in the tables the logarithm for a compound number, it must be sought for as being a whole number, and the index to correspond to that part of the number which is whole.

To perform Division by Logarithms.

RULE.—From the logarithm of the dividend subtract the logarithm of the divisor; the remainder is the logarithm of the quotient.

Example 1.—Divide 912 by 19.

Dividend, { 912......... log. .... 2·959995
Divisor, 19......... log. .... 1·278754 subtract.

Quotient, 48 — 1·681241 log. of quotient.

When decimals occur in the dividend or divisor, their logarithms are found as in multiplication of compound numbers.

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER IX.

To draw the handle or lever in fig. 31, proceed as in fig. 32. Draw the line, *c f*, *a b*; from *a*, with *a b* as radius, describe the semicircle *a b c*. From *a* measure to *m*, *e*, and *d*; through these draw lines parallel to *a b*, put in the shoulder *e d*, by taking half of the line *d*, and setting it off on each side of the line *a f*, and at the points thus obtained draw lines as at *m'*, parallel to *c f*. From *m* measure to *n*, and from this point describe the quadrant joining the line at *e*. From *d* or *a* measure to *f*, and through this draw *g f g*; from *g* with *g m'*, describe the quadrant, *g o*.

Another form of handle, frequently met with in machines, is shown in fig. 33. The centre line, *e b*, is first drawn, and any line, *g a*, at right angles to this; the radius of the circle, of which *e d* is an arc, is next found by trial; half the breadth, *d c*, is taken in the compasses, and laid off on the line *a g*, on both sides of the line *e b*, to *c* and *d*; from *c*, with the radius of the arc previously found, lay off to the point *a*, and from *d* to the point *g*; from these points, with the same radius, describe arcs. Other arcs meeting there are described from the points, *h e*; the radius, *f e*, being found by method just described for finding centres, *a g*.

Another form of handle is given in fig. 34. Draw two lines, *a b*, *o f*, at right angles to each other. From the copy take half the distance of the thickest part of the handle, between the points *o f*, and from the point, *c*, lay off on *o f* to the points *o f*. Find by trial the radius of the arc, *o b*; from the points *o* and *f*, on the line *o f*, set off this distance to the points *d* and *e*; from *e*, with radius, *e o*, describe the arc, *o b*; and from *d*, with radius, *d f*, the arc, *f b*. The point, *b*, will thus be found. From *b*, measure to the point, *m*; from *m*, on a line parallel to *o f*, set off *m n*, *m o*; at the thinnest part of the handle, as at *h h*, draw a line parallel to *d e*; from centre line, *a b*, with half *h h*, set off on each side, *a b* to *h h*. Find by trial the radius of the arc, *o h x*; and, with the distance found, set off from *h h* to the points, *f*, *g*; these points on the line, *f h g*, will be the centres from which the arcs, *n h*, *o h*, are described to meet those described from *d e*.

In fig. 35, which represents another form of lever handle, the centres are marked at *c c c c*.

In using the term "copy," it is understood that we mean a sketch similar to that given with each example, but *without* the dotted lines; these are put in so as to make one diagram serve for two purposes, in place of using two diagrams, as in figs. 31 and 32; one serving as the copy, as in fig. 31, and the other the elucidation of the method of copying it, as in fig. 32.

Fig. 36 represents a lever-hook, used in flax machines, &c., by which weights are suspended. To copy it first from any point, as *b*, describe two circles, as *b g*, *b f*. By trial find the centres of the arcs, *h*, *m*, and *o*; and join arcs described with these radii, with the circles described from *b*; the centres of the arcs, *h*, *o*, *m*, will be found at *c a*.

Fig. 37 represents a form of "thumb-screw," frequently used in machines. *e c* represents a screwed bolt, up and down which the nut, *e f d*, can be moved by the projecting snugs, *a b*. One half of this diagram gives the method of delineating it; the other half is finished. Draw any two lines, *e f*, *e c*, at right angles. From *e* measure to *d*. With half the distance of upper side of nut, from *d* set off on both sides of *e e* to *f*; and from *d* to *g* with half the under side of nut; join *f g*. Find the centres of the two circles, *a b*, and join them by a line, *a b*, parallel to *n f*; from *e* measure to *c*, where this line cuts *e c* at *c*; through *c* draw a line parallel to *n f*. With half the distance between *a b*, lay off from *c* to *b* and *a*. From these points describe the circles, *b a*. Find the centre of the arc, *o n*, as at *h*; and from *h*, with *h o*, join *o n*; finish as in the drawing.

In fig. 38, a representation is given of the form of handle used for furnace doors, cylinder covers, &c., &c. Lines, *c b*, *a d*, are drawn at right angles. The centres of the circles are found in these lines, as at *a b*, the radii being *b o*, *a n*.

In fig. 39, the elevation of a pulley is given. Draw any two lines, *o o*, *a b*, at right angles. Bisect *o b* on the point, *e*. From *o* set off to *b*, and draw *b e*; through *e* draw *e g*. With *e c* as radius, describe arcs at *g* and *e o*.

The circular plate with snugs, in fig. 40, is drawn by the method displayed in fig. 41. From the centre, *a*, a circle is described, with radius, *a d*; two diameters are then drawn, as

c b, *d e*, and the internal square formed by joining the extremities, as *c d*, *d b*, *b e*, *e c*; *f* shows one of the centres for describing the circular parts, *n n*. The centres of the snugs, *m m*, are found in the diameters, *b c*, *d e*, produced.

In fig. 42, the central arms, five in number, of a "pulley" are delineated. Describe a pentagon (see previous chapters) about the circle, and drawing lines from the centre of the circle to the corners of the pentagon; these lines form the centres of each arm. The arms may be found in fig. 42, by describing the circle, and drawing the diameter, *a b*, and dividing the circle into five equal portions, starting from the point, *b*.

In fig. 43, the central arms of a wheel with six arms is shown. The centre lines of each arm may be found either by describing a hexagon round the circle, and drawing lines from the centre, as in last example; or by drawing a diameter, *a a*, and dividing each semicircle into three equal parts at the points, *b*, *c*, *d*, *e*.

In delineating the small triangular framing in fig. 44, draw two lines, *a b*, *c d*, at right angles; from *c*, with half *a b*, lay off on each side *c d* to *a b*; from *f*, with *f b*, describe the arc joining *a b*. From *c* measure to *e*, and describe the small circle there; finish as in the drawing.

In delineating the snug with circular ends, in fig. 45, draw two lines, *a d*, *a b*, at right angles; from *a*, describe the circles, *a d*, *a e*; from *a* measure to *b*, equal to the distance from centre, *a*, to centre, *m*, found by trial; through *b* draw a line, *c b c*, parallel to *a d*. With *m n* as radius, describe from *b* a circle, *b o*; and from *c c*, small arcs joining this, with the circle, *d a*. We have only given half of the diagram, with centres; the other half is finished.

In fig. 46, the use of the ellipse or oval (for methods of describing this figure, see previous chapters) is exemplified. The figure given represents the cover to a gas retort, with circular snugs for bolt holes; *a b c* and *d* are the centres from which the arcs are described.

The diagram in fig. 47, representing the centre of a "step," is delineated by the method shown in fig. 48. Describe the circle, *d e*, equal to that in the centre of fig. 47. Draw a tangent to this, the line, *a b*, and describe the triangle, *a b c*, about the circle, *a*. From *d*, describe the large circle, *d m*, and draw the diameter, *d m*; divide the semicircle, *m n*, into three equal parts, and draw from the centre, *d*, to these points, as *d a f*. The centres of the circles, *o o*, *m m*, fig. 47, will be found in these radial lines, as at *e e e* and *c*.

The centre of a "turbine," shown in fig. 49, is delineated by the method shown in fig. 50. A circle, *a*, is described equal to the central one in fig. 49, and also the circle, *a e*; divide this into eight equal parts, and draw radial lines, as *a n*, *a f*, *a m*, *a h*, *a g*, *a s*, *a p*, and *a e*. The lines, *c p a m c*, *b g*, *a n b*, will give the centre lines of the four arms in fig. 49. The letters of reference in both figures will sufficiently explain the further construction.

A pulley, with curved arms, is shown in fig. 51; one half is represented as finished, the other half shows the method of delineation. Describe the two external circles, and the internal circle, *a*. Find the centres of the arcs forming the parts, *m n*, fig. 51; these will be found in positions corresponding to the two points marked with a +. Through these points, describe circles as shown by the dotted lines, *f e b d*, *g c h*. The points, *f*, *e*, *b*, *d*, are the centres of the arcs, forming the parts corresponding to *n*; the points, *g c h*, being those of the parts, *m*.

In fig. 52, we give half of a "shield" used for covering the moving wheels of a cotton machine. The centre from which the arcs, *b c*, are described is at *a*; the line, *e d*, being the centre line, the other part of the figure being on the other side of *e d*, and being a repetition of that given in the diagram.

In fig. 53 we give the representation of part of a framing, and in fig. 54 the method of delineating it. The corresponding letters in the two figures will amply explain the method of construction.

In fig. 55 we give the representation of the cap of a locomotive chimney; *e b* is the centre line, and *a* the centre from which the arc is described.

To draw the representation of part of a French boiler, in fig. 56. Draw the centre line, *a b*, from *a*, describe the circle, measure from *a* to *b*, and through *b* draw a line, *b e*, at right angles to *a b*. From *b* measure to *d*, and from *d* describe the circle, *d e*; through *d*, draw a line parallel to *a b*; from *d* measure to *f*, and put in the flange, *f n g*.

In fig. 57, a half elevation of a "plummet-block" is given; the other half of the diagram explains the method of construction. Draw the lines, *f d*, *f g*, at right angles; from *f* measure to *a*, and from *a* describe the circle, *a k*. Measure from *a* to *b* and *c*; *c* is the centre of the circle, *c e*, and *b* that of *b d*; *h i m* are the centres of the other arcs. The learner should draw both sides of this diagram complete.

Half of the centre plate of a water-wheel is represented in fig. 58. From *a* describe the circle, *a* 6; divide this into ten equal parts—it is only divided into five in the diagram, half only being shown. Through these points, as 2, 3, 4, 5, draw lines from the centre, *a*—these will give the centre lines of the arms, 5, 4, 3, and 2; from which their breadth is set off, as *e e* on the line 2. The centres of the arcs forming the extremities of the parts, *o g*, are found by describing circles from *a*, as *a n*, *a m*; and cutting these by radial lines from *a*, as *a n m*, passing through points in the circle, *a* 6, between the external lines of the arms.

Another form of centre is represented in fig. 59. The sides of this form an octagon, which may be described in the square, of which half is given, as *e b c d*. The centre of the wheel is at *a*, and is found by bisecting two opposite sides of the square, and drawing lines at right angles through these points—the point of intersection is the centre, *a*. The centre lines of the arms, *p p*, are obtained by drawing radial lines from *a*, as shown in the drawing, to *b*, *c*, and *g g*.

In figs. 60, 61, 62, 63, 64, and 65, we give diagrams of various parts of "framing," showing the methods of delineation.

In fig. 60, draw the centre line, *a b* and *b c*, at right angles to this—*a d* and *e* are the various centres.

In fig. 61, *a* and *b* are the centres, the horizontal and vertical lines meeting at right angles at *c* and *d*, these being joined by the arcs described from the centre, *a*. The dotted lines are not to be shown in the finished sketch.

In fig. 62, the centres are at *c* and *e*. The line, *a b*, is first drawn; the centre of the arc, *b g*, found by trial, and its distance, as *a c*, laid on *a b*, from *a* to *c*. The centre of the arc, *g d*, is also found by trial, and the point laid down by measuring its distance from the lines, *a*, *b*, and *d*, in the copy.

In fig. 63, the centres are at *a*, *b*, *g*, *e*, *f*. The exterior circle, from *a*, is first described, and a horizontal line, *c d*, drawn from this. The distance from *a* to the centre *b* is then found, and from *b*, with proper radius, a circle is described, meeting *c d*. The centre, *g*, is then found. With *a g* describe an arc, cutting this by another arc described from *b*; the point of intersection will be the centre, *g*; from *g* describe the arcs, and join the circles described from *a*, *b*, and *g*, by arcs described from *f e*, the radii being found by trial.

In fig. 64, the centres are at *c*, *g*, and *h*. Draw the lines, *a b*, *a c*; find the centre of the small circle, 1, and take its distance from the line, *a b*, and from *a* measure to *c*; through *c* draw a line to *e*, at right angles to *a c*; measure from *c* to 1, from 1 describe the small circle; from *c*, with radii, *c d* and *c e*, describe the arcs to *m n*; from 1, measure to *s*, and from *c*, with *c* 1, describe an arc; on this line the centre of the circle, *s*, will be found. Continue the arc, *c m* to *f*; find the centre of the arc, *f b*, and describe *f b*. Find the centre of arc, *a o*, and from *h*, with *h a*, describe arc *a o*.

In fig. 65, part of a framing is represented. Draw two lines, *a b*, *a c*, at right angles. On the line, *a i*, set off the various distances, *a c*, *a d*, *a e*, and through these draw lines parallel to *a b*. The arc, *o′ o*, is described from centre, *p*. The various dotted lines and circles are put in to aid the learner in describing the diagram.

In fig. 66, another example of part of framing is given. Draw two lines, *a b*, *a d*, at right angles. Find the centre of the circle described from *e*; measure from the line, *a b*, to *e*, and this from *a* to *f*; parallel to *a b* draw *f e*; on this line the centre, *e*, will be found. Describe the circle, *e d*, extend the line, *f e*, to *g*, measure from *e* to *g*, and set this distance from

e to *g*; join *d g*. Find the centre of the circle described from *h*; through the point draw a line parallel to *f g*, or with the distance, *m h*, set off from *a* to *h'*, and through this point draw a line parallel to *f g*; on this line the centre, *h*, will be found. Find the centre of the circle, *c*, and with the distance from *e* to *c* describe an arc; with the distance, *a c*, from the point *a*, describe another arc; the point of intersection will be the centre of circle, *c*; from *c* describe the arcs joining those described from *e*. Describe from *n*, *o*, *s*, the arcs, and join them by the lines as in the copy.

In fig. 67, the method of drawing a pulley is shown. Draw the two lines, *d e*, *a b*, at right angles, from *c* with half of *a b*, lay off on each side of *d e*, to the points, *a* and *b*; through these draw lines parallel to *d e*; from *c* as a centre, with *c d* or *c e* as radius, describe arcs joining these.

In fig. 68 we give an elevation of two covers of gas retorts. Draw a line, *a b*, and another at right angles to it. Find the centres of the circles, *d c*, from *a*, with *a c*, *a d*, set off on *a b* to *c d*. From these points describe the arcs, the radii of which will be obtained from the copy. Find the centres of the arcs described from *g h*, *m n*; join these with lines parallel to *a*; with the distance from the points, *d c*, on the line, *a b*, at which the lines, *g h*, *m n*, cut it, set off from *c* and *d* corresponding distances on the line *a b*; through these points draw lines parallel to *a*. The centres, *g*, *h*, *m*, *n*, will be found in these lines equidistant from the central line, *a b*. From *g h*, *m n*, describe the various arcs. Find the centre of the arcs described from *e f*, joining those described from the centres, *c* and *d*; through *f* and *e* draw lines parallel to *a*; take the distance from the point where these lines cut *a b*, to the points *c* and *d*, and set this from *c* and *d* on the copy; from *e* and *f* describe the arcs joining those already described from *c d*; finish as in fig. 68.

Fig. 69 represents the curved exhaust-pipes of a locomotive engine, leading from the cylinder to the draught blast-pipe. Draw *a b*, *c d*, at right angles. Find by trial the centres of the circles, *e*, *m*, *g*, and *s*. Draw through *e* a line parallel to *e b*, cutting *c d* in *f*; measure from *e* to *f*, and transfer this distance to the copy; draw parallel to *a b* a line through *f*; measure from *f* to *e*, and set it off on the line, *f e* to *e*; *e* is the centre corresponding to the centre, *e*, in the diagram; the position of the other centres are found by processes identical with this. To obtain the slope or angle of the flange near the top of the diagram, draw lines from the corner of the flange, cutting the line, *c d*, in the points, *n* and *i*. From *n i* measure to *e*, and transfer the distance from the point, *c*, in the copy to the line, *c d*; the position of the points, *n*, *i*, will thus be obtained, corresponding to those in the diagram in fig. 69. Measure, from fig. 69, from *i* and *n* to the point in the centre of breadth of flange, and transfer these distances from the points, *i*, *n*, in the copy, on both sides of *c d*; through the points thus obtained, as *p o*, draw lines; these will be the centre lines of the flange; finish as in the diagram.

FARRIERY.

CHAPTER II.

ANATOMICAL STRUCTURE OF THE HORSE.—OF THE SKELETON.

The skeleton of the horse consists of 238 bones, and are divided into those of the head, trunk, and extremities, or limbs. The following is a tabular enumeration of them:—

HEAD.

CRANIUM.

Frontal bone,		1
Parietal bones—Pair,		2
Occipital bone,		1
Temporal bones—Two pairs,		4
Ethmoidal bone,		1
Sphenoidal bone,		1
		10
Malleus, Incus, Stapes, Orbiculare,	Bones of the Ear,	4
Total,		14

FACE.

Upper jaw— Nasal bones, Superior maxillary bones, Inferior maxillary bones, Malar bones, Lachrymal bones, Palatine bones, Superior turbinated bones, Inferior turbinated bones,	Pairs,	16
Vomer—Single,		1
Lower jaw,		1
		18
Teeth,		40
Os hyoides,		1
Total,		59

TRUNK.

SPINE.

Cervical vertebræ,	7
Dorsal vertebræ,	18
Lumbar vertebræ,	5
Total,	30

THORAX, OR CHEST.

Sternum,	1
Ribs, 18 on each side,	36
Total,	37

PELVIS.

Ossa innominata,	2
Sacrum,	1
Coccygeal bones, varying from 13 to 18,	15
Total,	18

EXTREMITIES, OR LIMBS.

FORE.

Scapula, Humerus,		Shoulder bones,	2
Radius, Ulna,		Arm bones,	2
1st Row— Scaphoid, Lunar, Cuneiform, Trapezeum,	2d Row— Pisiform, Trapezoid, Os magnum, Unciform,	Bones of the Knee,	8
Large Metacarpal bone, Two small Metacarpal bones,		Leg bones,	3
Sesmoid bones—Fetlock,			2
Pastern bones,			1
Coronet bone,			1
Coffin, Navicular,		Foot bones,	2
Total,			21

HIND.

Femur—Haunch bone,		1
Patella—Stifle bone,		1
Tibia, Fibula,	Thigh bones,	2
Astragalus, Os calcis, Cuboid bones, Three Cuneiform bones,	Hock bones,	6
The bones below the hock correspond in name and number to those below the knee, viz.,		9
Total,		19

REFERENCES TO THE BONES OF THE SKELETON.

PLATE I.

This plate represents the skeleton, and exhibits the position of the various bones, when not invested by the muscles.

a a, The seven bones of the neck, called the cervical vertebræ.

b, The sternum, fore part of the chest, or breast bone.

c, The scapula, or shoulder blade.

d, The humerus, or bone of the arm.

e e, The radius, or bone of the fore arm.

f, The ulna, or elbow.

g g, The cartilages of the ribs.

h h h, The costæ, or ribs, nine of which unite with, or more properly are articulated to, the sternum, or breast bone; these are denominated the *true* ribs, and nine are united together by cartilages, and are called the *false* ribs. The total number of ribs are thirty-six, ranged in pairs—namely, eighteen on either side; occasionally there exist thirty-eight, and even forty ribs have been met with in some skeletons. They are distinguished by their numerical order, counting from before backwards.

i i, The carpus, or knee, consisting of seven small bones; in some instances, an eighth has been found. Six of these bones are ranged in rows, forming two tiers, each consisting of three pieces; the seventh is placed completely behind the others. The *first*, or superior row, is formed by the scaphoid, lunar, and unciform bones. The *second*, or inferior row, by the trapezoid, great, and unciform bones.

j j, The metacarpal, or shank bones; the larger metacarpal, or cannon, or shank bone, in front, and the smaller metacarpal, or splint bone, behind. The larger metacarpal bone is connected above with the magnum, unciform, and trapezoid bones, and laterally and posteriorly with the small metacarpal bones; and below, with the large pastern and sesamoid bones. The external splint bone supports the unciform; the internal, the trapezoid; both are attached to the large metacarpal bone.

k k, The upper pastern. Its situation is immediately under the cannon bone, with which, from taking an oblique direction, it forms an obtuse angle. It is connected with the cannon and coronet bones, and with the two sesamoids.

l l, The lower pastern, or coronet bone. It is situate between the pastern and the foot. It is connected with the pastern, coffin, and navicular bones.

m, The hoof, within which is situated the coffin bone, and nearly resembles the hoof in form, being almost semilunar. This bone is liable to change of form, dependent upon the morbid condition. The navicular bone may be regarded as an appendage to it. It is divided into wall, sole, tendinous surface, articulatory surface, and wings.

z z, The sesamoid bones. They are situate at the back of the articulation, formed by the pastern and cannon bones.

n n, The eighteen dorsal vertebræ, or bones of the back or spine.

The vertebral chain, or back bone, reaches from the occiput, 1, to the sacrum, which is situate below, *n*, at the superior part of the pelvis, continued from the vertebral chain between the ossa ilia. It resembles the lumbar portion of the spine, from which it declines with a slight bend, presenting a convexity externally, a concavity internally. In young horses, this bone consists of five distinct separable pieces, united one to another by a fibro-cartilaginous substance, which, in the adult animal, is converted into bone.

o o r, The six lumbar vertebræ, or bones of the loins. These are situate immediately over the haunch bones. In some subjects, there are only five of these bones.

o to *z*, The five sacral vertebræ, or bones of the haunch.

z to *z*, The caudal vertebræ, or bones of the tail. These are variable in number, from thirteen to eighteen. They are situate behind the sacrum, to which they form an appendage. The two, and sometimes three first bones, possess complete bony arches, from which arise one or two spinous eminences, giving attachment to the erectoris coccygis, and consequently they possess an interrupted spinal canal; in the following two or three pieces, the spinal arch becomes gradually more defective, and the closed canal degenerates into a channel, open above, and that in the four or five subsequent pieces into a simple groove, until at length all traces of such formation disappear.

p p, The haunch, consisting of three portions—namely, the ilium, the ischium, and the pubes, forming the lateral and lower portions of the pelvis. The form is very irregular, large and flat, broad at the extremities, which turn in different directions; the middle portions are contracted. This is likewise termed the hip, or edge bone. In the fœtus, this bone is capable of being separated into three distinctly formed pieces: the ilium, the largest division, the triangular plate in front; the ischium, the part projecting backwards; and the pubes, inferior and middle portion. They all contribute to the formation of the acetabulum, or basin of the pelvis; the ischium and pubes together, form the obturator foramen. These parts quickly complete their bony union after birth; and the ischium and pubes, the speediest.

q q, The femur, or thigh bones. The femur corresponds to the thigh bones—the veritable *os femoris* of a man. That in the horse enters into the formation of the part we call the haunch; while the tibia and fibula, the human leg bones, become in the horse the basis of the part we are in the habit of calling the thigh.

r r, The stifle joint, with the patellas, or knee caps, in front, 2 2. They are situate upon the trochial surface of the inferior extremity of the round bone. They are of a quadrangular form; convex externally, and irregularly concave internally. They are connected by muscles and the capsular ligament with the round bone, and by their own proper ligaments with the tibia.

s s, The tibias, or proper leg bones. These are situate between the stifle and the hock. When the limbs are resting on the centre of gravity, they are oblique; but contrariwise to the round bones, whose bases, or lower extremities, incline forwards. They are connected with the round bone above, and the os calcis below.

t, The fibula; it is situate behind the tibia, and attached to its superior portion, hardly extending half its length. This small and seemingly unimportant bone can be regarded but as an appendix to the tibia.

The tibia and fibula are equivalent to the leg bones in man, which bear the same name, and which are situate between the foot and knee in the human being. From want of attention to this fact, those unacquainted with the anatomy of the hind legs of the horse are so frequently puzzled, and confound the tarsus with the leg bone in man. Consequently, this point demands particular attention.

u u, The hock, or tarsus, composed of six bones. As the knee of the horse answers to the wrist of man, and is therefore analogically regarded as the *carpus*, so, in like manner, the hock becomes the correspondent part to the instep, and is consequently considered under the technical appellation of *tarsus*. It is composed of six small bones: they are, the astragalus, os calcis, os cuboides, and the os cuneiforma—externum, medium, and internum.

3 3, The knuckle bones, or astragalus, which is the uppermost bone of the hock; the one which alone supports the tibia. It is distinguished by its upper pulley-like formation, which is entirely articulatory, and consists of two bold semicircular prominences, with a deep capacious groove between them; the whole admirably adapted to the two grooves, parted by their middle projection, in the lower extremity of the tibia. The posterior surface is extremely irregular, exhibiting four polished places for articulation with the os calcis, and between them very rough porous interspaces, for giving strong ligamentous attachment. The lower surface is smaller than either of the others, and is irregularly flattened, and almost entirely articulatory; it is embraced by the upper part of the large cuneiform bone. From a pit at the bottom of the pulley-like adaptation, takes its origin the extensor pedis accessorius.

4 4, The os calcis, or point of the hock, which is that projecting part behind. It is of an irregular figure, and divided into two portions, called the body and tuberosity. The body is the lower portion, and the tuberosity the projecting part behind.

5, The cuboid bone, situate in the outer part of the back; its form is oblong, from back to front. Its internal surface is irregularly excavated and rough, and has three places of articulation—one posteriorly, for the great cuneiform bone; the other two smaller, one anteriorly, and one posteriorly, for the middle cuneiform bone. The upper surface has two articulations, with a little pit between them; one for the astragalus, a

larger one for the os calcis. The inferior surface presents two articulatory places; one for the external splint bone, and the other for the cannon bone.

6, The large cuneiform bone, situate immediately underneath the astragalus. Its form is triangular; the broadest side turned forwards, the salient angle backwards. It is flat, both above and below. Its superior surface is adapted to the under part of the astragalus. The inferior surface articulates with the middle cuneiform, and also, next the internal angle, with the small cuneiform bone. So that it connects with the astragalus, cuboid, middle, and small cuneiform bones.

7, The middle cuneiform bone. It lies immediately under the large cuneiform; the upper surface unites with the large bone, and the lower surface with the hind cannon bone.

v v, The metatarsal bones of the hind leg, likewise termed the hind cannon, or shank bone. As the cannon bone of the fore leg is said to be the representative for one of the longest metacarpal bones of the human hand, so this bone, in comparative anatomy, is regarded as the representative of one of the metatarsal bones which compose the foot, although it is, in the horse, the bone of the hind leg. It so nearly resembles the fore cannon bone, that the two, at first sight, appear to be precisely alike; there are differences, however, between them, and, in particular, three. 1st. The bone of the hind leg is longer by about one-sixth part than the bone of the fore leg. 2d. The body of the former is rounder and more prominent anteriorly than that of the latter. 3d. The superior articulatory surfaces are different, the one being such as is adapted to the middle and small cuneiform and cuboid bones, the other accomodates the inferior row of the bones composing the knee.

w w, The pasterns of the hind feet, including the upper and larger bone, *w w*, and the lower pastern, *y*, and the coffin bones, *x x*. These so closely resemble their fellows in the fore feet, that a description of them would only be a repetition.

THE BONES OF THE CRANIUM.

PLATE III., FIGS. 1 AND 2.

The head is of an oblong quadrangular form, with its sides broad and flattened, narrow and contracted above and in front, rather large at the opposite points, and hollow interiorly. The nose, with the mouth, are remarkable for their great length and capacity; and the cranium is no less striking for its diminutive sphere. It is articulated with the spine, by which it is suspended, and is composed of two parts, namely, the cranium and face.

The division of the head into so many bones is a remarkable proof of design. When the fœtus of the foal first assumes a form, and manifests vitality, the skull is merely of the consistence of jelly. It gradually becomes harder and cartilaginous in substance. This, in course of its progress to perfection, gradually becomes absorbed, by means of a series of vessels seated in the brain, which are denominated absorbents, and ultimately bone is deposited instead of cartilage, which, however, does not become perfectly consolidated until after birth. In the flat bones, which compose the skull, this bony deposit takes place from the centre, radiating in all directions. Consequently, these numerous bones are so many more centres, so that the formation of bone is so much more rapid, and becomes perfected at the time when the necessities of the animal require it. After the birth of the foal, however, the edges of the various bones are still soft, which is another wise provision, for this pliancy enables the edges of the bone to lap over each other, consequently rendering parturition more easy, and likewise materially to its safety. Indeed, without this yielding of the bone, and its compressibility, the birth of the animal could hardly be realized alive.

FRONT VIEW OF THE SKULL OF THE HORSE.

PLATE I., FIG. 1.

The cranium, or brain-case, is small when compared with the bulk of the body in general. The bones of which it is composed, are for the purpose of protecting the brain. This portion of the head consists of the nine following bones, viz.:

1, 1, The frontal bones, situate in the higher fore part of the head, or cranium, generally denominated the forehead, and which, in the living horse, is in many instances marked by a white patch of hair called a star. They are united together by a curious dovetail-like or serrated process, which gives great strength to the junction, and admirably adapted for the protection of the brain, which is situate behind the upper portion of them. Lower down, this serrated junction is much less complicated, being destined for the protection of the cavity of the nose, which requires less strength. The form of the frontal bones afford an excellent criterion for judging of the breed of a horse.

In the blood-horse, the forehead is broad and angular, with the face gradually tapering to the muzzle. It is this prominent forehead which gives that intelligent and lively expression to his countenance, which forms a remarkable contrast to that of the common cart horse, whose forehead is hardly wider than the face.

2, 2, The parietal bones, or walls of the skull. These are situate in the upper portion of the cranium. They are of a quadrangular form; vaulted, externally convex, and interiorly concave. Their external or convex surface is divided longitudinally by a mesian crest, which is bifurcated anteriorly, and shows the course of the suture existing in the young animal, into two lateral convexities; these are most elevated towards the higher external angles, and their surfaces, although otherwise smooth, contain a few scattered small foramina, and are imprinted by the continual action of the muscles covering them, these impressions growing deeper with age. In the foal, indeed, generally until the second or third year, a longitudinal suture is observable, dividing this bone into two correspondent parts.

3, The occipital bone, or bone of the hinder part of the cranium. This is situate in the back portion of the cranium. Its form is symmetrical, irregular, exhibiting convexities and projections outwardly, concavities and a large circular aperture inwardly. In the foal, this bone consists of four pieces, which, in after age, become two, and in the full adult animal becomes a single bone.

4, 4, The temporal bones, or bones of the temple. These are situate on the latter portions of the cranium. They consist of four separate pieces, in pairs, each of which is irregular in its form. One pair exhibits vaulted ovoid plates, surmounted by curved or hooked projections; the others are solid convex forms, very hard and white. In the human being these pieces are united, and are considered as the squamous and petrous portions of one bone. Although the same names are preserved, the portions are in reality distinct bones.

5, 5, The temporal fossa, or pits above the eye. These are situate between the temporal bones and zygomatic arch. These cavities form a pretty good criterion of the age of the horse. At the back of the eye, there is a considerable portion of fatty matter, which enables the eye to revolve easily, and without friction. When horses are old, or after disease, this fatty substance is absorbed; consequently, the eye sinks, and the pit above the eye becomes deeper. Dishonest and low horse dealers frequently practise a deception to take away this sunk cavity, by piercing the skin, and with a small tube or blowpipe, fill the depression with air, and produce that appearance which is manifested in youth. This trick is vulgarly denominated *puffing the glims*. But if this part is pressed upon, the trick will easily be detected.

6, 6, The zygomatic, or yoke-shaped arch.

7, 7, The super-orbital foraminæ, or holes above the orbit for the passage of the nerves and blood-vessels, supplying the forehead. The small holes beneath are for the passage of vessels which supply nourishment to the bony substance. In some horses, there are several of such holes.

8, 8, The orbits in which the eyes are situated, and destined for their protection. They are composed of unequal portions, coming from four of the bones of the cranium, and from three of those of the face, viz., the frontal, ethnoid, sphenoid, and temporal bones.

9, 9, The lachrymal, or tear bones.

10, 10, The malar, or cheek bones. These are situate on the anterior external parts of the orbits; they are of an irregularly triangular form, presenting a broad basis forwards. These bones contribute to the formation of the orbits, maxillary

sinuses, and zygomatic arches, and their articulations exhibit a sort of dovetail mechanism, and are connected with the temporal, superior maxillary, and lachrymal bones.

11, 11, The nasal bones, or bones of the nose. These are situate in the upper portion of the face, where they constitute the roof of the cavity of the nose. In form, they are vaulted, thin, elongated, and externally convex, concave internally, broad posteriorly, tapering and terminating in a sharp point anteriorly. One of these bones, singly, represents the section of a hollow cone, split longitudinally, but the two, when joined together in the face, have the form of a heart. They are connected with the frontal, superior and anterior maxillary, and lachrymal bones.

12, 12, The superior maxillary bones, or that portion of the upper jaw containing the molar teeth, or grinders. They are situate in the upper side portions of the face. These are divided into the facial surface, the palatine surface, and nasal surface. The facial surface is partially subdivided into the front superior and back inferior portions by a protuberant ridge, called the superior maxillary spine, which forms one continuous line with the zygomatic spine, and terminates abruptly opposite to the third molar tooth. The upper subdivision is considerably larger, and affords attachment to the masseter. Somewhat above the middle of the upper surface, opens the infra-orbital foramen, which is traversed by blood-vessels and nerves, which bear the same name. The palatine surface shows the concave side of a vaulted, half-arched, oblong plate, called the palatine process, or bony palate, which forms the partition between the cavities of the nose and mouth; this plate denticulates with the palate bone behind, and with the anterior maxillary bone before. The surface is bounded along the outer side by the alveolar processes (which fix the teeth in their sockets), and between it and them runs a groove for the conduit of the palatine artery. The nasal surface forms the outer side, and half of the floor of the nasal cavity.

13, 13, The infra-orbital foraminæ, or holes below for the passage of branches of nerves and blood-vessels, to nourish the lower portions of the face.

14, 14, The openings into the nose, with the bones forming the roof of the palate.

15, 15, The inferior maxillary, the lower portion of the upper jaw bone, which is a separate bone in quadrupeds, containing in them the incisor, or cutting teeth, and the upper tushes, at the point of union between the superior and inferior maxillaries.

16, The upper incisors, or cutting teeth, which are vulgarly called the nippers.

SIDE VIEW OF THE SKULL.

PLATE III., FIG. 2.

1, The frontal bone, beneath which are situate cavities in the adult animal, called frontal sinuses.
2, The parietal bone.
3, The occipital bone.
6, The zygomatic arch.
7, The super-orbital foramen.
8, The orbit, which contains the eye and its appendages.
9, The lachrymal, or tear bone.
11, The nasal bone.
12, 12, The superior maxillary bone.
13, The infra-orbital foramina.
14, The opening into the nose.
15, The inferior maxillary.
16, The upper incisors, or cutting teeth.
16,* The lower incisors.
17, The molars or grinders of the upper and the lower jaw.
18, The tushes.
19, The posterior maxillary, or under jaw.

AGRICULTURE.

CHAPTER XI.

DRAINING.

We have now given an abstract of the science upon which the art of agriculture mainly depends, and we have stated the servants employed, and the general plan of operations upon a farm where the mixed husbandry is practised in those parts of the country where this mode of farming is most successfully prosecuted. It now remains for us to dwell at somewhat greater length upon some of the topics connected with farming, which are not indeed practised every year in succession, but upon the due performance of which a good deal of the farmer's success depends.

We begin with the important subject of DRAINING.

It may be laid down as an axiom, that in all heavy or semi-heavy soils, and in all soils with anything approaching to an impervious subsoil, properly constructed drains are the foundation of all good farming; and that, if these are neglected, the business of the agriculturist is almost certain to end in bankruptcy.

The object to be attained in draining is to remove, or rather to prevent, stagnant water remaining where the roots of the crops are to be, or are. If this water is allowed to accumulate, two evil consequences follow. One of these is, the food of the plant is presented to its roots in too diluted a state, and the plant so situated is not able to take up the quantity that it otherwise would, and therefore does not attain the size and maturity it otherwise would. The other is, that, owing to the evaporation constantly going on from the stagnant water, the soil is kept in so low a degree of temperature as not to have sufficient heat present to enable the vegetation upon it to come to perfection. Perhaps stagnant water has other injurious effects than those upon crops. At any rate, every one conversant with farming is fully persuaded, that to imperfect drainage all bad and unprofitable agriculture is attributable. We may extract upon this head the authority (certainly not an insufficient one) of Stephens:—"Observation," says this gentleman, "has shown that stagnant water, whether upon or under the surface, does injure the growth of all useful plants. Be the cause of the injury what it may, experience assures us that draining prevents all its bad effects. The deficiency of crops, frequently attributable to unskilful husbandry or apparently dry land, arises, in my opinion, from the baleful influence of *concealed* stagnant water; and want of skill is here shown, not so much in the mismanagement of the arable culture, as in neglect to remove the concealed moisture; for, let the culture be ever so skilfully conducted, it will never produce so great and good crops from damp as from naturally dry or thoroughly drained land. A conviction has been forced upon me by long and extensive observation of the state of the soil, over a great portion of the kingdom, that the neglect of draining is the true cause of most of the farming to be seen, and that a single farm does not exist, not already thoroughly drained, which would not be much the better for draining."

The same distinguished agricultural writer farther observes, when speaking of the injury inflicted upon crops by water stagnating over an impervious subsoil:—"We cannot inquire too minutely into the extensive injury sustained by the soil and its products, by the stagnation of rain-water upon an impervious subsoil. Most of the soil of Scotland consists of loam of different consistence, resting upon tenacious clay of uneqal depth. Where the soil is shallowest, it is injured by the stagnant water remaining constantly beneath it; and where deepest, it is injured by chilly exhalations, arising from the water below. The direct injury done to soil by stagnant water, may be estimated from these effects. Manure, whether putrescent or caustic, imparts no fertility to it; the plough, the harrow, and even the roller, cannot pulverize it into fine mould. The new grass contains little nourishment for live stock; and, in old, the finer sorts disappear, and are succeeded by coarse subaquatic plants. The stock never receives a hearty meal of grass, hay, or straw, being always hungry and dissatisfied, and, of course, in low condition. Trees acquire a hard bark and stiffened branches, and become a prey to parasitic plants. The roads are continually soft, and apt to become rutted, whilst ditches and furrows are either plashy, or like a wrung sponge ready to absorb water. The air always feels damp and chilly, and from early autumn to late in spring, the hoarfrost meets the face like a damp cloth. In winter, the slightest frost encrusts every furrow with ice, not strong enough to bear

one's weight, but just weak enough to give way at every step, while snow lies long lurking in shady corners and crevices. In summer, mosquitoes, gadflies, greenflies, midges, and gnats torment the cattle, and the ploughman and his horses, from morning to night. In autumn, the sheep get scalded heads, and are eaten by the maggots of the green and carrion flies during the hot blinks of sunshine. These are no exaggerated statements, but such as I have observed in numerous situations —in hill, valley, and plain; and wherever these phenomena occur to a considerable degree, it may safely be concluded that stagnant water lurks beneath the soil. Entertaining this opinion, and knowing these parts, it is not surprising that I urge the practice of draining with much earnestness."*

There can be no doubt but that the proper person at whose expense the draining of a farm should be done, is the landlord or proprietor. The improvement effected by it upon the land is of a permanent, or at any rate approaching to a permanent character. But in actual practice, the burden generally falls either entirely or partially upon the tenant, who has, of course, a lease. If the landlord do it, it is considered by competent judges sufficient if he add to the rent eight per cent. upon his outlay, always presuming the lease to have the usual term of nineteen years. If, however, the tenant do the draining, he is considered to be entitled to deduct from the rent, inasmuch as his interest in the improvement is only temporary, eighteen per cent. upon his disbursements. The drainage bill has modified this, by lending sufficient money to do the draining, on condition of receiving six and a half per cent. for twenty-two years, when the debt is liquidated. The common plan now is for the proprietor to pledge the land as security for the repayment, but the tenant to pay the annual sum agreed upon.

It seldom or never happens that a whole farm is drained at once, but a portion only is so operated upon every year until the whole be finished. The portion usually selected is the lea land intended to be in oats. The grass is mown or consumed by cattle; the work begins in autumn, and finished ere the time for sowing the oats has come on. By thus proceeding no crop is lost. Upon those farms (daily turning fewer in number) where part of the land is summer fallowed, draining is performed upon it, and the long days of summer enable the work to be rapidly done.

If the farm have a considerable slant, it is necessary to begin with the lowest portion first. If, however, the farm be pretty level, it matters not where it is commenced. On such level ground it may not be easy to decide upon the fall by the eye, and in order to ascertain this, for the purpose of having a sufficient outfall for the drained water, a spirit-level is used. This fall from the outlet should not be less than a foot in two hundred and twenty yards. In like manner, the fall in the field to be drained must be provided for, and should be about the same. In perfectly level land, the only means of attaining this is to cut the drain deeper at the lower end, and nearer the surface at their upper.

It is important to remember that too great a slant in drains is injurious, and the water passes so rapidly through them as to drain the land so fast, as to wash away very valuable ingredients from the soil. One mode of obviating this difficulty is to make the drains broader, and thus cause the stream of water in them to be shallow, and therefore less rapid in its flow.

It appears now a settled point, that, save in exceptional cases, the drains should be at least three feet deep.

Sometimes drains are executed by labourers, directed by the farmer, and under the superintendence of either the hedgeman or the grieve. But a common and better plan is to let it to experienced contractors. These are, however, under the superintendence of a farm-servant.

The first thing to do, after having ascertained the limits, is to fix upon the position of the main drains into which the water brought by the other drains is poured. They, of course, must occupy the lowest part of the field. Should the field be very level, these main drains are made deeper than the small ones. Indeed, in most situations, many are of opinion that the main drains should be about six inches deeper than the other ones. The main drain, we should remark, should not be within five yards of a hedge or tree, for fear of the roots pushing their way into it.

After having fixed upon the place for the main drain, that of the small ones must next be determined. These, of course, must be so arranged that they have a fall toward the main drain, into which they are to pour their contents. They are made to run as nearly as possible at a right angle with the main drain.

The distance at which drains should be put from one another varies very much in different soils. Of late, the practice of making them very deep and wide apart has been gaining ground. Mr. Mechi, for instance, boasts that his land is perfectly drained with five-feet drains placed forty feet apart. But Scottish farmers, who have visited this gentleman's farm, are of opinion that the land is not sufficiently drained. And we know of many instances where those wide apart drains have not rendered the land dry, although the very same land has been thoroughly dried by placing them closer. Perhaps, in the Lothians, the land requires to be thoroughly dried to have three-feet drains every eighteen feet, or four-feet drains every twenty-four feet.

When the position of the main and small drains have been fixed upon, the workmen remove the mould and as much of the subsoil as is necessary. The superintendent then measures the depth and breadth of the drains, to ascertain if they have been made according to contract. He also ascertains that the drain has the due degree of fall. This he does by means of levelling staffs, and also by making little dams across the drains; and if no water come into them, he throws in a few bucketfuls, so to be able to test them.

Then comes the laying of the tiles. First of all, the soles are laid firmly upon the ground, and a little imbedded in the earth. Then upon these are placed the tiles, each tile being made to rest upon the back of one sole, and the half of the next. Earth is next put firmly between the tiles and the sides of the drain, as high as the top of the tiles, in order to fix them firmly in their places. This earth is taken from that which had been taken out to make the drain. The remainder of the earth is now put in, either with the spade or the plough.

The cost of draining in this manner varies according to local circumstances. A common price of tiles is about a pound the thousand, and of soles about ten shillings. Perhaps, on an average, about three pounds per acre may be set down as the cost of effectually draining average land. But, of course, this must greatly depend upon the depth and distance of the drains.

By way of illustrating the pecuniary profit to be derived from draining, we may extract the following from one of the most practical and best of our agricultural writers. The most palpable advantage is the *profit* it returns to the farmer:—"I am clearly of opinion," says Mr. North Dalrymple of Cleland, Lanarkshire, "that well-authenticated facts on economical draining, accompanied with details of the expense, value of succeeding crops, and of the land before and after draining, will be the means of stimulating both landlords and tenants to pursue the most important, judicious, and *remunerating* of all land improvements. The statements below will prove the advantage of furrow draining; and as to the *profits* to be derived from it, they are great; and a farmer has only to drain a five acre field to have wider proof upon the point." Without entering into all the details of the statements given by Mr. Dalrymple, it will suffice here to exhibit a few general results. One field, containing fifty-four Scotch acres, cost £303. 7s. to drain, or £5. 12s. per acre. The wheat off a part of it was sold for £11, and the turnips off the remainder for £25. 13s. 4d. per acre. The soil was a stiff chalky clay, and let in grass for twenty shillings per acre; but in 1836, after having been drained, it kept five Cheviot ewes, with their lambs, upon an acre. Another field of eighteen acres cost £5. 9s. per acre to drain. The wheat off one part of it realized £13, the potatoes off another £15. 15s., and the turnips off the remainder £21 per acre. The land was formerly occupied with whins and rushes, and let for twelve shillings an acre; but when let for pasture, after having been drained, Mr. Dalrymple expected to get fifty shillings an

* Book of the Farm, Vol. II

acre for it. It may be mentioned that the drains made by Mr. Dalrymple were narrow ones, thirty inches in depth, filled eighteen inches high with stones or scoria from a furnace, and connected with main drains thirty-six inches deep, and furnished with tiles and soles. Mr. James Howden, Wintonhill, Tranent, in East Lothian, found, from experience, that although drains should cost as much as seven pounds per acre on damp heavy land, thorough draining will repay from 15 to 20 per cent. on the outlay. These instances will suffice for Scotland. For England, on the estate of Teddisley Hay, in Staffordshire, 467 acres 9 poles were drained, at an expense of £1,508. 17s. 4d.—that is, £3. 7s. 7d. per acre. The former rent was £254. 10s. 9d., and after the drainage it rose to £689. 3s. 1d.—giving an increase of 28½ per cent. on the outlay. And for Ireland, on the estate of Castleshane, county Monaghan, belonging to Edward Lucas, Esq., 57 acres, 2 roods, 13 perches were thorough drained for £269. 11s. 4d., yielding an increased value of the land of 30 per cent.

It may safely be affirmed that the method of draining that we have described with tiles and soles, if at proper depths and suitable distances, is a most effectual and perfect system. The expense of it has led to the substitution of the junction of the tile and the sole in the pipe; and these pipes have been found to answer perfectly well. Sometimes they have been made with only a bore of one inch, which is too small, inasmuch as the current in such is not of sufficient rapidity to wash away accidental impurities, which tend to clog drains. Many people are suspicious that the water cannot penetrate through the structure of the pipes. This is quite a mistake; the unglazed earthenware admits the passage of water well enough; and, indeed, in the tile and sole, the water does not get into the cavity at the point of junction of the two, but through the pores of their substance.

Drains are liable to many obstructions. Water-plants sometimes grow in them, and at last chokes them. The writer of this recollects seeing an immense quantity of moss (he was then too young to detail the species) extracted from a drain that had ceased to deliver water. The roots of trees, if the drains are made too near them, frequently effectually destroy them. Frequently, too, incrustations formed by the substances taken in by the water from the soil and subsoil choke them up. The two most common of these are limestone and oxide of iron. The dead bodies of vermin have sometimes temporarily obstructed them.

As draining is of most consequence of all upon heavy wet clays, and as it is most universally performed in winter, it is very trying and severe work to the labourer. The drainer, clad in his ordinary garb, must be often very wet, and always very dirty. The Earl of Westminster, when performing some draining operations, contrived a dress for the workers, which appear to deserve imitation. It consisted of large leggings and armlets of leather; and perhaps the place of leather might be supplied by some of the waterproof materials.

The system of draining land for farm purposes by the tile and sole, or the pipe, is, we believe, the best, and it is the one almost universally followed in the districts which we have selected, as containing the best cultivated land. Two other modes of draining, however, require a passing notice. The one of them is—

Stone Draining.—In this kind of draining the lower part of the drain is filled with broken stones, instead of with tiles and soles or pipes. The drain is cut in exactly the same way as for tiles, save that the base is made broader. The great matter appears to be to make the stones as much of a size as possible, and to have these sizes small ones. Perhaps all the stones should be sufficiently small as to pass through a rim three inches in diameter. The stones are made to occupy about eighteen inches from the bottom, and are beaten pretty close together by a wooden beater. Sometimes a duct is formed at the bottom, by means of flat stones; and it has been proposed to so place a tile.

The expense of draining with stone, of course, mainly depends upon the cost at which stones can be got and broken; and, generally speaking, stone draining costs more money than tile draining. Perhaps the extra cost amounts to as much as twenty-five per cent.

In some badly-farmed districts, instead of stones, sticks or straw are used, with the notion, we fancy, that, when they decompose, the space they occupied will not collapse, but form a channel or kind of natural tile.

The other method of draining to be noticed is the Elkington, and is principally confined to removing the water of large springs and the like. This is a very expensive mode of draining, and consists in conveying the water under ground in built conduits. Common furrow draining cannot convey away the water from permanent springs; and ponds, lakes, and morasses cannot be drained by such, not only because they could not carry away a sufficient quantity of water, but also, in many instances, the drains require to be at a great depth. When these purposes require to be served, the Elkington system of draining is the most effectual.

The drain intended to take away the water, say of a lake, must be as low, of course, as the lowest depth of water to be removed. A common error in digging the drain is to make it unnecessarily broad, thereby adding to the already great expense. It is difficult to conceive a necessity for making it broader than allows the labourers to work in it. In a great many instances the sides will have a tendency to fall in, and require to be restrained from doing so by planks and stobs of wood, arranged after the fashion of the grave-diggers. When the drains are dug, the conduits are built of stone, with a stone sole, care being taken that a fall is preserved. When the conduit has been built, it is common to shut up the end of it with a wisp of compressed straw, which, while it allows the passage of water, will not permit earthy impurities.

Another leading feature in Elkington's plan was employing the auger to tap the spring, when the depth of the drain was insufficient. For details regarding this, we must refer to "Johnston's Treatise on the Elkington Mode of Drainage."

Many attempts have been made to contrive instruments that may be drawn by horses to excavate drains. These, however, but partially effect their purpose, cost a good deal of money, require an immense number of horses to pull them, and are only applicable to land quite free of stones. As a general rule, draining must be done by manual labour.

One of the advantages of drained land is, that, owing to its freedom from superfluous moisture, it can be much sooner worked after rain, and generally during winter. The saving thereby effected, in having the ground ready in time in spring, and in preventing men and horses from being idle in winter, is very great, and is one of the many instances that farming affords of showing the importance of doing everything in the very best possible manner.

BOTANY.

CHAPTER VI.

ON LEAVES AND THEIR ACCOMPANIMENTS.

Leaves are membranous expansions, proceeding from an exposed shoulder of the roots of plants, or from their trunk, branches, and flowers. Those from the root are called *radical* (*radix*, root) leaves; when the stem gives rise to them, they take the name of *cauline* (*caulis*, stalk), Plate III., fig. 8; and when supplied by the branches or flowers, they are termed respectively, *ramal* (*ramus*, a bough), Plate III., fig. 9, and *floral* (*flora*, relating to blooms), Plate III., fig. 10. Though awanting in many of the simpler kinds, leaves form important organs in all the higher orders of plants. They may admit of convenient study under the heads of development, arrangement, form, structure, and function.

I. With regard to *development*, the leaf is a normal point, terminally or laterally continuous to the axis of the stem. There are two sorts of leaves; those that come first are denominated *seminal* (*semen*, seed), Plate III., fig. 7, or cotyledonous, (κοτυληδών, a hollow), and the others that succeed are *primordial* (*primus*, first, and *ordo*, rank). Now these two classes of

leaves always rotate or succeed each other; for where a leaf has made its appearance during one season, a leaf-bud comes to be formed during the season after, in the *axil* (*axilla*, arm-pit) or angle already made for it by the leaf with the stem. But as the leaf-bud is rudimentary of the branch, its minute physiology falls to be traced under that article.

Along with the progress of its vegetation, a base comes into view, connected with the support of the leaf. Its attachment to the stem, therefore, is either direct or mediate; when direct, the leaf is called *sessile*, Plate III., fig. 14; when mediate, *petiolate*, Plate III., fig. 12; and when these characters are, as it were, met together in one, the common organism takes the name of *frond*, Plate IV., fig. 27. These appellatives, however, allow of more particular explanation.

We have said that when the leaf is joined to the stem without any intervention, it is called *sessile* (*sessilis*, a seat) or sitting. Of the sessile configuration, the caper bush affords an example.

When, however, a leaf-stalk is interposed from the stem, it is called *petiole* (*petiolus*, a little foot), and the leaf prolonged from it becomes consequently named *petiolate*, as in the ranunculus. It is the flattened flexibility of this instrument that occasions the trembling motion of the aspen. A *sheathing* or *vaginal* (*vagina*, a case) form, Plate III., fig. 18, takes place, when the leaf envelopes the stem downwards, and for this purpose is formed into a tube, by union of the edges of its expansive petiole. Wheat, oats, or grasses, may readily occur to the reader as familiar instances.

In a number of plants, as in the bean family, the petiole has developed near its lower extremity, either on itself or on the stem, an appendage called the *stipule* (*stipula*, husk), which, for the most part, is produced in pairs, Plate V., fig. 1. Plants possessed of this organ are *stipulate*, while those destitute of it are known as *exstipulate*.

In other cases, again, as in the vine and pea, the petiole, instead of being terminated by a leaf, is wrought into a climbing apparatus called the *tendril* (*tendrillon*, Fr.) or *cirrhus* (*cirrus*, curl), Plate V., fig. 1.

With regard to sessile and petiolate leaves in common, the two following terms are used, semi-amplexicaul, and amplexicaul, which differ only as to the extent of the attached base. If sufficiently enlarged to embrace half the circumference of the stem, the leaf is *semi-amplexicaul* (from *semi*, half, *amplexor*, infold, and *caulis*, stalk). The *amplexicaul* leaf embraces the whole circumference of the stem, so as to meet with a rising edge around it, Plate III., fig. 15.

A combination of all the connecting parts—leaf, leaf-stalk, and stem, so as to individualize them—constitutes what is meant by a *frond*. Thus, the ascending trunk of a fern used to be regarded as a stipe, and the leaves as fronds—the real trunk being a rhizome, or stem, that creeps along the ground. But this term, as applied to algæ, lichens, ferns, and palms, has lost its precise meaning from the progress of physiological botany, and is gradually passing into disuse.

In the infancy of the leaf, a continuity subsists with the petiole or stem, but articulations become subsequently formed at varying points. When permanently continuous, the leaf decays while still attached to its axis. A joint is placed in certain instances, between the vaginal or stipulary portion and the petiole. It is to the blade of the orange that its winged petiole is attached; and in cactus opuntia, the leaflets are produced each from the summit of that below, Plate IV., fig. 19. But when the leaf is articulated to the stem, a *scar* or *cicatricula* remains. Those trees which shed their leaves annually are *deciduous*; when the leaves remain fixed for a longer term than one year, they are *evergreen*.

In a state of full development, the superficial plane of the leaf ranges through every angle of exposure, the horizontal being predominating. The characters to be observed are:—

Coriaceous or leathery.	Plaited or plicate—sycamore.
Crisp—(*Rumex crispus*).	Shining or glossy.
Curled, rough, wrinkled.	Smooth.
Fleshy—palms.	Spotted.
Glaucous or sea-green.	Wavy or undulated—(*Rheum undulatum*).
Glutinous.	

II. The *arrangement* of leaves is a department of this study, named *phyllotaxis* (φύλλον, a leaf, and τάξις, order). The position of leaves on plants is no random matter, but is a thing reduced to law. If we take a closely-leaved branch, with intervals between the leaves sufficiently large to make the operation easy, and follow from one leaf to another as they succeed in ascending order, the branch shall be found to turn round in the process, and to exhibit specific amounts of revolution before leaf shall stand directly above leaf in the series. This is the *generating* or *phylloplastic* (φύλλον, a leaf, and πλαστικὸς, formative) *spiral*, lining through every leaf of a cluster; and has a normal tendency, arising perhaps from the manner of vegetation, in an upward and lateral direction.

There are definite points spaced out upon the trunk or branches of plants, on which leaves or leaf-buds are produced. These points are *nodes* (*nodus*, a knot); and the intervals betwixt them, or the part of the plant from node to node, are *internodes*, or *merithals* (μέρος, a part, and θαλλὸς, a bough). When a leaf is equally produced on either side of the axis at the same level, the leaves are said to be *opposite*, Plate IV., fig. 22. When more than two leaves are arranged at the same level, they are called *verticillate* (*verto*, to turn), from surrounding the stem in a sort of ring; and the collection is a *verticil* or *whorl*, Plate IV., fig. 20. When opposite leaves ascend, at the distance of the internodes, in pairs at right angles to each other, they are *decussate* (*decusso*, to cut across), Plate III., fig. 9. When one leaf has no other precisely opposite to it, but the next occurs at a different height on the stem, the leaves become *alternate*, Plate IV., fig. 23.

The spiral arrangement thus formed, is characterized in different plants according to the number of leaves in the cycle. When arranged in two rows, and the third leaf is situated directly above the first, they are *distichous* (δὶς, twice, and στίχος, order). When the fourth leaf is directly above the first, the arrangement is *tristichous* (τρεῖς, three, and στιχος, order), and so on. An arrangement of five, called *quincunx*, is frequently met with in the garden apple, pear, and cherry.

It is proper to add, that the arrangements we have mentioned are subject to some irregularity; different species of the same genus pursue different directions at the same time, in the trunk and branches. The number of leaves in different whorls has varied in the plant *Lysimachia vulgaris*. It has been also noticed, that interruption of growth, or vigorous cultivation, has changed one arrangement into another.

These cases, however, instead of proving an exception to the law, only suggest its details as synchronical. An equal exposure to air and light—the shape of the stem, as round or square, as in gabiate plants—and the mode in which branches are disposed, whether pyramidal, bushy, or pendulous, are among the final ends to which the law administers.

III. Let us pass on to the *forms* assumed by leaves. Though amongst unnumbered thousands which meet the view, hardly two can be found exactly resembling each other in size and beauty, yet they are easily reducible within special forms. To insure the requisite distinction with such multitudes, various terms are employed by botanists; and from their aptness and frequency of occurrence, it is of importance for the student to master them. The forms of leaves are usually divided into simple and compound; by the first is meant a class of leaves which consist of one piece only, however variously divided. The latter include those having two or more leaflets issuing from a leaf-stalk. We do not, however, consider this arrangement adapted for easy acquisition; to aid the memory, we shall therefore group the terms employed in each division, under modifications which take their rise—1st, from the nature of the apex; 2d, from the margin, and the segments bordered by it; and 3d, from the resemblances offered to the geometrical forms of other well-known objects.

1st. Forms defined by the nature of the apex; that is, the opposite extremity to the base or end which adjoins the petiole.

Acuminate, where a leaf, without being tapered from the petiole, is drawn into a long point, Plate II., fig. 42.

Mucronite (*mucro*, stiff point), where the apex is hard and short, without tapering.

Retuse (*retusus*, blunt), the apex flattened or slightly depressed, Plate II., fig. 46.

Truncate (*trunco*, to cut off,) the apex ending abruptly, Plate I., fig. 18.

2d. Forms from the margin, and the segments bordered by it. The marginal edge taken as one, receives the name of *circumscription;* and when it is marked by an evenness throughout, the leaf is known as *entire* (*integer*, whole). Slender hairs arranged round the edges entitle it *ciliated* (*cilium*, eyelash) or fringed, Plate II., fig. 50; and it is *spinous*, when the leading ribs are stiffly extended beyond the border of the leaf, Plate V., fig. 2. When, instead of projections, injected recesses are formed with a round sinuosity, occasioning a division of the surface uniform with the leaf, of the least depth it can offer, it is called *dentate*, Plate I., fig. 30. If the teeth be inclined upwards and downwards, with sharp points both at the inner and outer angles, it is *serrated* (*serra a seco*, to cut), that is, marked like a saw, Plate I., fig. 31; or if each tooth be subdivided by a smaller one, the form is *doubly serrated*, Plate I., fig. 32. When the teeth are more or less triangular and pointed in direction of an undivided base, it is *runcinate* (*runcina*, a large saw), as in dandelion. When the teeth are rounded and blunt, it is *crenate*, Plate I., fig. 38; but when they are of increased size, to approach downwards towards the mid-rib or petiole, the leaf is *notched*, or *lobed*, or *cleft*, Plate I., fig. 19; and these divisions are called *segments*, *fissures*, or *partitions*, Plate I., fig. 16. The following redundant synonymes are often applied without sufficient precision, both to simple and compound leaves:—

Three Leaflets.	Five Leaflets.	Seven Leaflets.
Ternate,	Quinate,	Septate,
Tripartite,	Quinquepartite,	Septempartite,
Trifid,	Quinquefid,	Septemfid,
Trifoliate,	Quinquefoliate,	Septemfoliate,
Three-lobed,	Five-lobed,	Seven-lobed,

or many-lobed, above that number of divisions. When all the leaflets issue from the top of the petiole they are *digitate* (*digitus*, finger) or *digitipartite*, because spread out like fingers on a hand, Plate II., fig. 4. When the segments leave an undivided space in the middle point from which they diverge, the leaf is *palmate* (*palma*, the inner part of the hand) or *palmatifid*, Plate I., fig. 22. When two partitions are formed laterally to three or more primary ones, with divisions on the inner margin, the leaf is *pedate* (*pes*, a foot) or *pedatifid*, from a supposed likeness to a bird's claw, Plate II., fig. 5. When an oblong segment, or several pinnæ at the apex are rounded, while those at the base diminish in size, the leaf is *lyrate*, resembling a lyre, Plate II., fig. 64; and when there is a concavity on each side, as in *Rumex pulcher*, it is *panduriform* (πανδοῦρα, a violin), Plate II., fig. 63. When the segments, laterally arranged on the petiole, are numerous, broad, and deep, the leaf is *feather-veined* or *pinnatifid* (*pinna*, wing, and *fidus*, cleft), from being arranged like the barbs of a feather on their shaft, Plate I., fig. 23, Plate II., figs. 6–14; but, on the other hand, when the divisions are narrow, the form is *pectinate* (*pecten*, a comb). Subdivisions may pass upon these forms when they become *bipinnatifid* or *bipinnatipartite*, Plate III., fig. 18, and so on. In all cases, when a set of compound leaves invest a petiole that is branched, the leaf becomes generally *decompound*. Lastly, when the petiole becomes branched once, twice, thrice, the leaflets are advanced to the cognomen of *supra-decompound*, Plate III., figs. 19, 20.

3d. Resemblances offered to the geometrical forms of well-known objects. It may be premised, that the flat surfaces of a leaf are called its *paginæ* (*pagina*, a page). The comparisons which they supply are for the most part derived from mathematical figures, from animal organs, and from mechanical instruments: thus—

Acute, Plate II., fig. 41, and *obtuse*, Plate II., fig. 40, may be illustrated by the Rosebay and Mistletoe. *Linear*, when the leaf occupies a narrow strip from the base to the apex, as in the pine tree, Plate I., fig. 7, Plate IV., fig. 25. This form is also called *acicular*, *oblique*, or *unequal*, when the development on one side of the mid-rib or stem is greater than on the other, Plate II., fig. 1. For the same reason, when the sides are symmetrically developed, it is *equal*, Plate I., fig. 10. *Orbicular* and *round* have been already explained, vol. i., p. 584; but two other forms, nearly associated, require to be adduced. *Peltate* (*pelta*, a buckler), is when the petiole finds an attachment to the middle of the inferior face of the leaf, Plate III., fig. 13; and *perfoliate*, when a single leaf completely envelopes the stem by a protrusion of its base, like a cup, Plate III., fig. 16½. *Elliptical*, Plate I., fig. 6; *oval*, Plate I., fig. 4; *oblong*, Plate I., fig. 5, may be readily understood.

Cordate is when rounded lobes are formed heart-shaped, Plate I., fig. 10; when this form is inversed, it is *obcordate;* and when the deficiency at the apex is only slight, it is *emarginate*, or taken out of the margin, Plate II., fig. 44. *Reniform* is kidney-shaped, Plate I., fig. 9. As the length of the veins may preponderate at the base or apex, so as to flatten it out in a corresponding form, it is either *ovate*, egg-shaped, Plate I., fig. 3, or *obovate*, the reverse of the other. *Auricular* is when the base of the leaf is furnished with two ear-like appendages (*auricula*, a little ear).

A hollow leaf, like the onion, is denoted by *fistular* (*fistula*, a pipe), Plate II., fig. 62; and *ascidian* (ἀσκίδιον, a small bag) is distinctive of the pitchers. *Subulate* (*subula*, an awl) tapers like the object indicated by it, Plate I., fig 8. *Lanceolate* is from *lancea*, a spear, Plate I., fig. 6. *Sagitate* (*sagitta*, an arrow) has lobes acutely prolonged downwards, Plate I., fig. 13; but in *hastate* (*hasta*, a halbert), they proceed at right angles, Plate I., fig. 15. *Ensiform* (*ensis*, a sword), *acinaciform* (*acinaces*, a scimitar), Plate II., fig. 56; *dolabriform* (*dolabra*, an axe), Plate II., fig. 57; *cuneate* (*cuneus*, a wedge), Plate II., fig. 45; and *spathulate* (*spatula*, a spoon), Plate IV., fig. 28—are all sufficiently expressive.

IV. The internal *structure* of the leaf falls to be considered after its external form.

This structural arrangement varies with the medium in which it is destined to subsist, whether water or air. The simplest formation is always present in the aquatic leaf; there is no vascular system there—no epidermis nor any stomata. In place of these, the submerged leaf is composed of a congeries of cells, more or less elongated and compressed, compactly united on the surface, but disposed irregularly in the interior, with vacant spaces termed *fenestrate* (*fenestra*, a window), which contain air as a floating power. In some instances, the cells or their walls are filamentous, as in Ouvirandra fenestralis.

A gradual ascent takes places in the scale of organization, as the leaf is exposed to contact with the light and air. The readily ascertained parts which enter into the consistence of aerial leaves, from the centre outwards, are as follow:—1st, *vascular tissue*, a formation made up of vessels or fibres, which may be spiral, porous, or woody; 2d, *cellular tissue*, otherwise called *parenchyma*, occupying spaces left by the course of the vessels or fibres; 3d, an *epidermis*, or outer skin, enveloping the whole.

1st. If we suppose that the central part of a leaf-bearing twig consists of vascular tissue, we have still to carry the idea of the same structure passing through the petiole when present, and then dilating from the point of junction throughout the leaf, into conspicuous *veins*, *ribs*, or *nerves*. Each of these lines, we say, includes a division of the vessel-shaped tubes, which run compacted through the petiole into the woody substance of the twig. The leaf, therefore, differing in no way from the other parts of the tree, except in a flattened attenuation, is the *limb*, *blade*, or *laminar merithal* (μέρος, a part, and θαλλὸς, a sprig) of the axis from which it is descended. The projections thus ramifying like the arms of a lever, on mechanical no less than physiological principles, may be considered as a perfect provision.

Veins are characteristic of the higher classes only of plants; for in the lower tribes, represented by submerged leaves, their place is occupied by condensations of elongated cellular tissue. They are arranged into two kinds, reticulated and parallel.

When the middle bar of a leaf is only a continuation in the line of the petiole, with minuter bars spread from its base or sides, and arranged into two lateral sections, each with subdivided radiations, it takes the name of *reticulated*, or netted. Of this nature are the beautiful skeletons which may be picked up beneath every holly hedge. The disposition of the bars

may be *unicostate* (*unus*, one, and *costa*, a rib), that is, with one mid-rib, Plate II., fig. 52; and *costate* or *multicostate*, with two or more leading ribs, Plate II., fig. 53.

What is called *parallel* venation, is open to an arrangement of convexity in the ribs, if they proceed from the mid-rib to the margin; or of convergence and divergence in that distribution.

It remains to be added, that the nervous structure of leaves corresponding with the organization of seeds, is indicative of the great divisions of the vegetable kingdom. In the netted races, woody tubes, sometimes but not invariably, associated with dotted tubes, are arranged around a central pith, which radiates in medullary plates, reproducing itself on the *circumference.* In those which have parallel veins, the trunk is formed of woody tubes interspersed as guards through spiral and dotted vessels, which are reproduced in the *centre* of the trunk. In acrogens or acotyledons the leaves vary with the structure, and are typical of the plan on which that has been formed.

2d. The *cellular structure* of a leaf is dispersed through the spaces enclosed by the veins. In addition to the epithet of *parenchyma*, this portion has obtained the names of *diachma* (δια, among, and χυμα, tissue), *mesophyllum* (μεσος, middle, and φυλλον, a leaf), and *diplœ* (διπλοΐς, double covering). When gaps occur in the leaf, as in Dracontium pertusum, it is in consequence of this tissue being irregularly diffused over the surface. In leaves having a vertical suspension, as in some of the Australian acacias, the sky seems to affect the tissue of both sides with an equal structure. But, for the most part, the sides contain two distinct series of cells, the contents of which consist of green or colourless granules, called *chlorophylle* (χλωρὸς, green, and φυλλον, a leaf). The upper cells are oblong, blunt, perpendicularly arranged, and so closely related, that only a few small interstices appear. On the lower side they are irregular, branching, horizontally inclined, and cavernous, or abounding with hollow openings, like cavities.

3d. Over all this frame of netted work and investing pulp, is spread the *epidermis*, an outer covering, thin, transparent, and porous. It is composed, as may be seen from the top and bottom of last figure, of a single series of compressed cells; and probably, from being developed by separate membranes of the bark, they differ in aspect on either side of the leaf. The upper surface is found generally denser, smoother, and more deeply green, sometimes hard, and frequently shining. The lower is dull or pale in colour, soft, punctuated, and beset with light down or hairs. Upon both surfaces, but especially on the lower, are distributed the bodies called *stomata.*

The *functions* of leaves form too important an inquiry, not to be pursued in a separate chapter. We shall, therefore, draw these remarks to a close, by an observation on what may be termed their universal uses.

Sturm has said, that "leaves, the ornament of trees, form one of the chief beauties of Nature, and are the pride of our gardens, fields, and woods." — *Reflections I.*, 319. As an auxiliary in the equipments of the heaven-allotted habitation of earth, no place or thing is exempt from their salutary influences. They invest the rocky waste with verdure, and create a blandishment for the animated races to convene beneath their shadow. In this respect they are the harbingers of civilization itself. There, the sports of the insect people are carried on—

> "In a wailful choir, the small gnats mourn
> Among the river sallows, borne aloft
> Or sinking, as the light wind lives or dies."

From ancient time they have formed altars of song to the feathered tribes; and the nightingale still serenades from its grove, and the swallow twitters from the palm-thatched eaves. Under their mantling foliage, the cattle from a thousand hills find shelter and felicity. Nor to man are their blessings less choice. Leaves contain officinal qualities that give them importance in domestic and medical usage—such as, artichoke, brocoli, borecole, cardoons, cabbage, celery, cress, endive, fennel, leeks, lettuce, parsley, parsnip, rhubarb, sea-kale, succory, sorrel, spinage. Also, balm, bhang, coltsfoot, costmary, chamomile, foxglove, hellebore, hemlock, hyssop, lavender, mallow, peach, peppermint, pennyroyal, rosemary, rue, sago, savory, spearmint, tarragon, tansy, thyme. But to the susceptible mind, the moral shall ever surpass the physical quality. The highest lessons of wisdom may be gathered from these rustling monitors, while within the quiet haunts which they keep green and cool, passion may be dispersed, and counsels of sweet consolation be inspired.

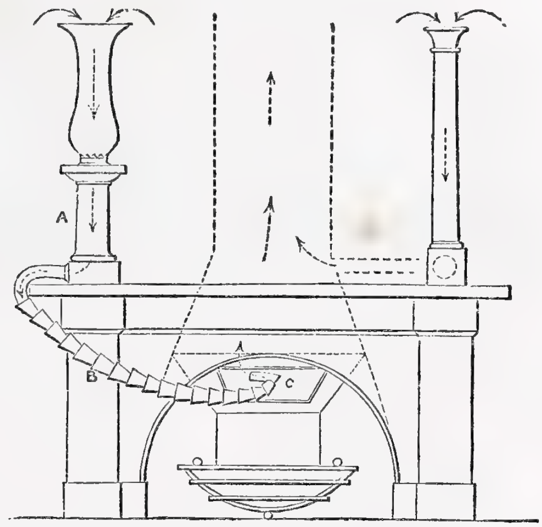
VENTILATION OF APARTMENTS IN DWELLING-HOUSES.

CHAPTER III.

SYPHON VENTILATOR—WALKER AND WIGGINTON'S PLANS FOR VENTILATION IN CONNECTION WITH CHIMNEYS.

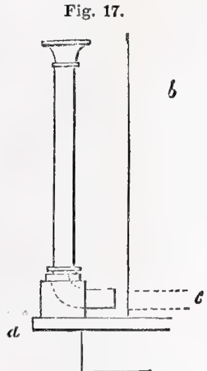
Where there is a fireplace to an outer wall, the tube or channel forming the short leg of the siphon may be placed outside, the lower extremity of the tube entering the chimney above the valve of the grate, by an aperture made in the brick-work, and the upper extremity entering the room near the

Fig. 16.



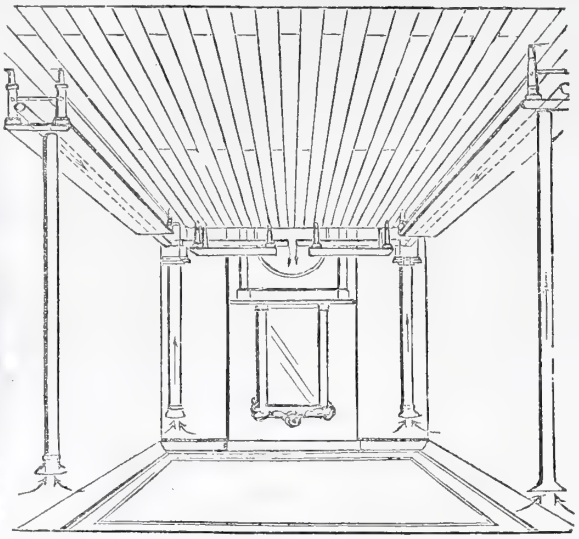
ceiling; thus the upper orifice alone will be seen in the apartment. In fig. 16, the long hollow pillar to the right of the sketch forms the short leg of the air-siphon, and is connected with the chimney by a tube. A "portable ventilator" is shown, fixed to the left of the same sketch. An ornamental hollow vase, A, is connected to the fire flue by a flexible metal tube, B, the extremity of which hooks on to the edge of the valve, C. By this arrangement, the foul air in a sick apartment can easily be withdrawn. In all cases where we have adopted this plan, we have found it invariably successful. If there is no fire in the grate, a smoke-board should be fitted tightly, so as to fill up the fireplace. Fig. 17 shows another method of fitting up the siphon as a "portable ventilator." An opening is to be cut through the brickwork just above the mantel shelf, so as to make a communication with the interior of the chimney. This aperture should be circular, and fitted with a metal tube, with a lid or cover to stop the aperture when the ventilator is not in use. The short leg of the siphon is made by the hollow pillar and stand, which rests on the mantel

Fig. 17.



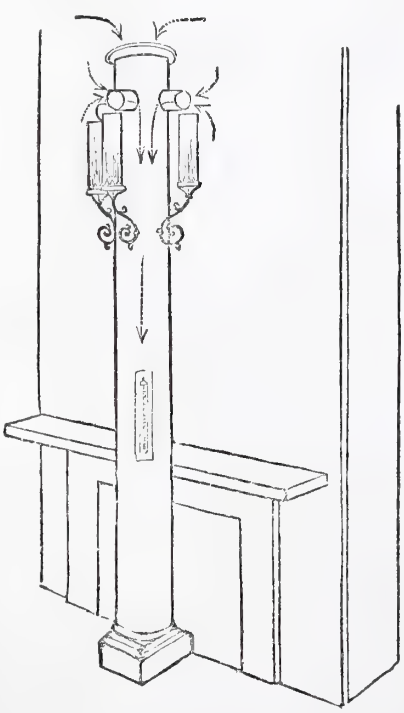
shelf, and is provided with a metal collar, which fits tightly into the tube forming the communication to the chimney. Fig. 18 represents the method of ventilating a school or ball-room by

Fig. 18.



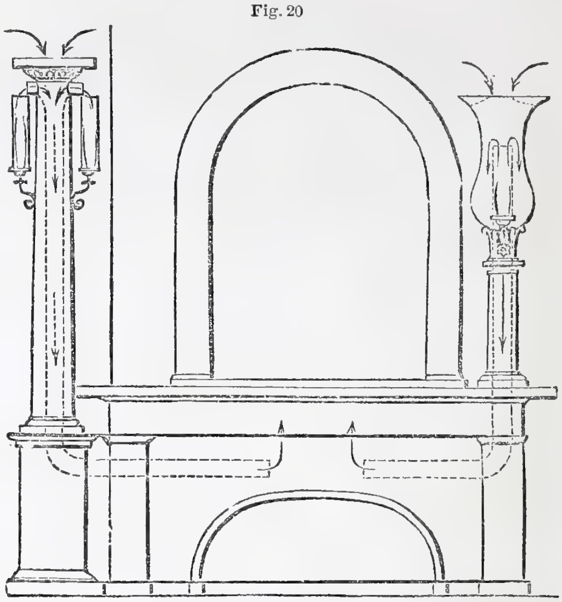
this means; tall pillars, hollow, having their apertures near the ceiling, and connected with the chimney. The fact that heated and even hot air descends the short leg of the siphon with facility, and is discharged by the longer, renders this system of ventilation peculiarly well adapted for removing the products arising from the combustion of gas. The sketch in fig. 19

Fig. 19.



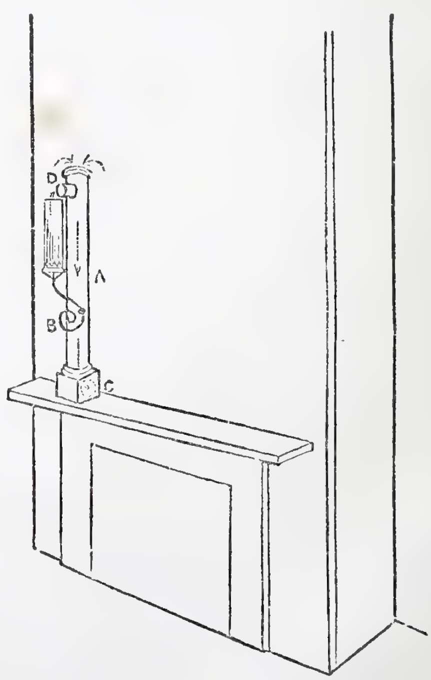
represents a pillar forming the short leg of the ventilating siphon, communicating with the chimney forming the long leg. To this pillar, branches with argand gas-burners are affixed, each flame being surrounded with the ordinary glass chimney. From the pillar lateral tubes project at right angles; these are so arranged that the upper edge of the glass chimney, nearest the mouth of the horizontal tube, would be on a level with the edge of the projecting tube, and so near as almost to touch it. By this arrangement, if the heated air from the gas flames was not influenced by the air siphon, it is obvious that they would pass freely up into the atmosphere; if, however,

Fig. 20



the ventilating current is really existent, and passing down the tall pillar, it is obvious that the products of combustion from the gas flames will be drawn through the horizontal projecting tubes, and passed down the pillar. This is, in fact, found to be the case, in numerous experiments which we have instituted.

Fig. 21.

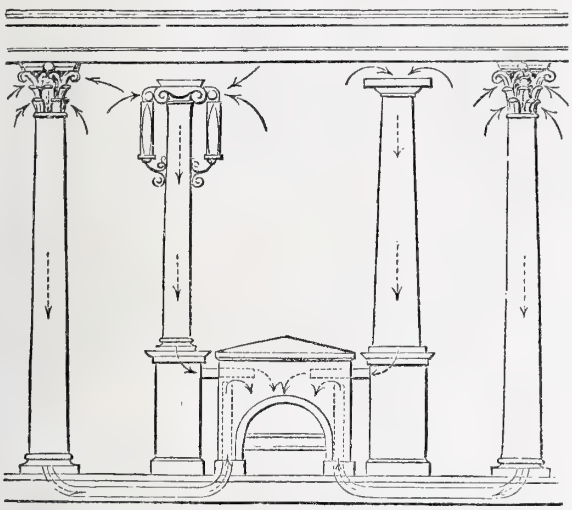


We have invariably found the products drawn through the lateral tubes, and this without any fire in the fireplace connected with the chimney forming the long leg of the

siphon. To test, in the strongest way, the truth of this, we have held writing-paper at a short distance above the orifice of a glass chimney, so near, that, under ordinary circumstances, the paper would have been instantly scorched; yet so rapidly was the heated air drawn down the lateral tubes, and away from the glass chimneys, that the paper was not discoloured.

Another point to be noticed is, that the hotter the interior of the pillar becomes, the quicker is the current down it; this is shown by the thermometer placed in the interior, as in the sketch; its variations being observable through the glass in front of it. Figs. 20, 21, and 22 represent different methods

Fig. 22.



by which the products of combustion from gas can be effectually withdrawn from an apartment. We have been thus particular in explaining and illustrating fully this system; because we have seen numerous instances in which it has been carried out, and the results of which have been so remarkably satisfactory that we have no hesitation in recommending its adoption, satisfied that, where the principle is properly attended to, it will be efficient. Not the least recommendation of the plan is the facility with which it can be carried out without interfering with the architectural details; on the contrary, it gives remarkable facilities for ornamenting the tubes employed. The patentee is Dr. Chowne, of Connaught Terrace, Hyde Park, London. By the addition of another adjunct, chimneys can be made to give most effective aid to the production of venilating currents; this is done by building, alongside of the flues for conducting away the smoke, smaller flues for conducting the heated air from the apartment. Suppose *a a*, fig. 23, is the chimney flue, and *b b* the smaller one alongside; the heated smoke passing up *a a*, will raise the temperature in *b b*, and the ventilating current up *b b* will withdraw any air which may be supplied to its interior. To admit the air of the apartment to the ventilating tube, all that is necessary is to cut an aperture in the chimney breast near the ceiling,

Fig. 23.

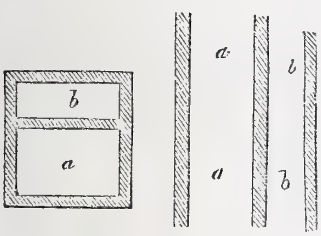
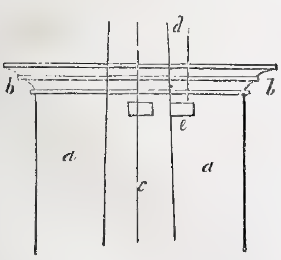


Fig. 24.



communicating with the interior of the tube, as shown in fig. 24, where *a a* is the front of the chimney breast; *b b* the cornice; *c c* the chimney flue; *d* the ventilating flue; *e* the orifice admitting air to the interior of *d*. This orifice may be marked with an ornamental grating. In place of having an orifice to the front, thus making it conspicuous, it may be made in the side of the projecting jamb, if the chimney breast is made to project, as in the majority of brick-built houses. This plan is very efficacious; and as the orifice is not furnished with any valve, there are no moving parts to get out of repair; again, it is impossible for smoke to pass into the apartment. The ventilating tube will have to be constructed at the same time with the chimney flue; hence this plan is only available—except in some special cases—where the house is being constructed.

In place of having the two flues constructed separately, a plan of combining the two in one piece has been carried out, and with a considerable economy of space and labour in putting up. Fig. 25 represents one length (two feet) of the "ventilating chimney tube;" it is made of burnt pottery ware; the smaller flue is the ventilating, and the larger the smoke flue. Fig. 26 represents the half plan of a fireplace, with the tube in each jamb; that to the right taking the products from a room below that in which the fireplace in the diagram stands. In fig. 27, a stack of chimney tubes is represented, showing the facility with which, from their square form, a "stack" can be constructed. By the use of these tubes, considerable saving is effected in the brickwork required for the chimney breast. "In a dwelling, three stories high, for instance, consisting of six rooms, or two dwellings of three rooms each, the whole of the six chimney tubes and ventilating flues may be carried up in one tubular stack; the tubes, as they proceeded upwards, would be firmly tied together, and secured by the floors; and at the top, outside the building, might be held together by an iron hoop, concealed by an ornamental moulding. In the two lower stories, the egress openings would not be in the centres of their respective chimney breasts; but as they would each require a frame of iron or brass, another and similar frame might be fixed on the other side of the centre line. The hollow spaces that would be left under the elbow should be filled in with brickwork, and the front and sides of the whole mass plastered, which completes the chimney breast all the way up."* Where the chimney flues as usually constructed are used alone, three flues will give a breadth to the chimney breast of 6 feet 2 inches; the projection of jamb from face of wall being 19 inches, with the ventilating flues, the width would be reduced to 5 feet 9 inches, the projection, 16 inches, thus adding to the dimensions of the room. By inserting in the interstices, *c c*, *d d*, fig. 27, one brick, a recess for the grate, 27 inches wide, is obtained; by adding two bricks, the recess may be increased to 3 feet.

Fig. 25.

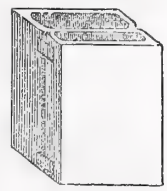


Fig. 26.

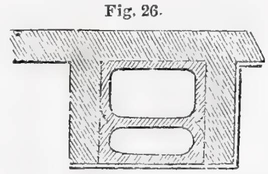
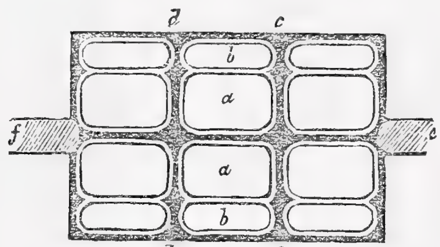


Fig. 27.



* Walker's Hints on Ventilation.

The cost per lineal foot is about 1s. 9d. The patentee is Wm. Walker, engineer, of Manchester.

Ranges of cottages, &c., can have their smoke and vitiated air removed from the apartments by a modification of this plan of separate ventilating flues, in conjunction with the chimney or smoke flue. One of the plans suggested by an able authority in ventilation, is illustrated in fig. 28. Let the smoke from the fireplaces of the range of cottages, be carried to one central chimney, *a a*; let this be surrounded by another and exterior chimney, leaving space between the two; this space is divided into flues, *b b*, fig. 29, into each one of which the vitiated air from one apartment is led; in place of having the space, *b b*, divided, it may be left open all round the inner flue, *a a*, tubes leading concentric from each apartment communicating with the space, *b b*.

Fig. 28.

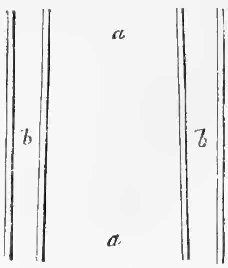
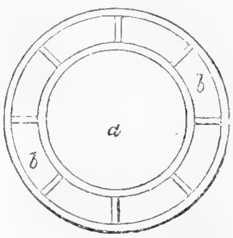


Fig. 29.



Mr. Wigginton, the architect, of Derby, who has devoted much time to sanitary matters, has recently introduced a plan of ventilating the apartments of a number of adjoining cottages, which, from its compactness and cheapness, we here illustrate; for the description and illustrations, we are indebted to the pages of the 'Artisan.' "The main funnel, or smoke flue, *n*, fig. 30, is formed of earthenware tubes. The tubes composing this, instead of being bedded or built close up to the brickwork, are placed in the centre of a shaft formed in the brickwork, which is of sufficient size to allow a space of $2\frac{1}{2}$ inches round the inner tube, as at *l l*. The inner tube is kept in its position by a header in the brickwork, at every 2 feet in height. A better way would be to have projecting snugs to each of the tubes, about 3 inches broad, $1\frac{1}{2}$ inch thick, and of length sufficient when built in the shaft, *l l*, to allow of the space of $2\frac{1}{2}$ inches round, by which means the inner tube would be well supported. Access from the various fireplaces is had to the interior of the inner smoke flue by apertures marked *m m*, which may be made of earthenware tubes; the communication between the rooms to be ventilated, and the ventilating shaft, *l l*, is made by means of the ventiducts, *o o*. The main flue, *n*, as in section, *n n*, fig. 31, should be bent at the base, and inclined to the exterior of the building, having a valve at the lower extremity, closed externally by an air-tight lid or door. This would render it easy of cleaning, and withdrawing the soot. Branch flues from the fireplaces, of a much smaller diameter, should communicate with the main flue through the walls, which would be found from the smallness of the throat, as it were, efficacious in carrying off the smoke, and easy of sweeping by a small brush, throwing the soot from the room; obviating thereby the disagreeableness of carrying the soot through the room, and its consequent disarrangement. The top of the main shaft should be secured by a cowl, or louvre-constructed head, to keep out the weather, and break the force of the wind, as well as to preserve the entire heat of the funnel from flying off. The heat imparted to the main shaft by the smoke of each fireplace would be very great, and would again impart itself to the air chamber, between the brickwork and the tube, rendering the air sufficiently light to create a current strong enough for its purpose of ventiduct. By this arrangement it would not be possible for any stoppage to take place, but, on the contrary, insure a perfect action, not dependent upon the wind or weather, or upon the care, for one moment, of the occupants; thus possessing a peculiar interest in its adaptation to the homes of the working classes, where neglect of good appliances are, through ignorance or carelessness, of general appearance."

Fig. 30.

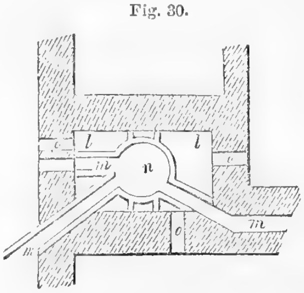
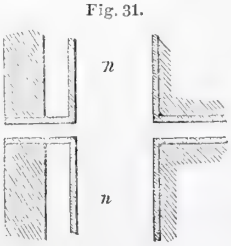


Fig. 31.



It is obvious, however, that the ventilation of our apartments, in which we spend by far the greater portion of our time, will not be placed in a thoroughly satisfactory condition, until our domestic architects bear in view, and carry into effect, plans which are to be incorporated and carried on in conjunction with the other portions of the building, as much as a door-way, a window aperture, or a chimney flue. It certainly is somewhat remarkable, while for so many years we have been theoretically acquainted with the evils of breathing impure air, and the necessity that exists for carrying it away from the interior of our apartments as fast as possible, that our architectural arrangements are so opposed in practice to what good theory dictates, that they could not be more admirably arranged, if the end they had in view were to keep in the foul atmosphere of our apartments. If the structural arrangements had in view this end, and the mixing of the impure air thus kept in with the fresh air, which is allowed to enter as best it can through chinks of doors or windows, "architects might be challenged to contrive anything better adapted to secure them;" and this is the opinion of an architect, no mean authority, either in the department of design or construction.

YATE'S FIRE-PROOF CEMENT.

Most of our readers are doubtless aware that all plastic compositions or cements hitherto proposed, set on the exterior surface first, on account of the action of the atmosphere, and from this cause arises the fact, that they are found liable to become detached or separated from the wall or surface to which they may be applied. Under these circumstances, it is obvious that such substances can have little effect in preserving combustible materials from fire, as the approach of heat invariably causes them to crack and fall from the surface of the structure upon which they are placed. The object of the present invention is to provide against this evil, by causing the composition to set or concrete first upon the surface to which it is applied, and so on, by degrees, until the dried portion reaches the external surface, as well as to resist the effects of fire or water. The preparation is formed by two separate processes, the results of which are by admixture made to act upon each other, thus:—1 lb. of bark or $\frac{1}{4}$ lb. of gall-nuts, ground to a fine powder, is boiled in two quarts of water, until one half the water has evaporated; this is then mixed with 7 lbs. of dry fire-clay. This done, the clay is to be dried and re-ground, and submitted to a like operation a second time, the object being to imbue the clay with as much of the tanning principle as possible. This is the first preparation. The second composition is prepared as follows:—$\frac{1}{2}$ lb. of glue is dissolved in a pint of water, to which is added $\frac{1}{4}$ lb. of slacked lime; this mixture is to be boiled, and the ingredients well blended together, when 7 lbs. of the fire-clay is to be added, the whole being again dried and reduced to powder. The mode of drying resorted to, is either to expose it to the action of the sun, or to an artificial heat not exceeding that of boiling water. These two separate compositions are now to be intimately blended together while in a state of powder, when eight times its weight of sulphate of lime (plaster of Paris) is to be added in a dry state. To this mixture is now added a quantity of silica, amounting to twice the weight of the plaster of Paris, previously applied. The silica may be either in the state of well-washed dry sand, or any ground siliceous substance, as granite, flint, &c. These several ingredients, with water, being properly mixed, produce the required cement.

For coloured or fancy plaster composition, as marble, &c., the following alteration is to be made in the mixture:—1 lb. of glue is added to 2 oz. of slacked lime, which is to be boiled, diluted, and mixed, as before described. To one part of this mixture the colouring matter is added, which is ground in, and to the other, 14 lbs. of carbonate of barytes, the latter portion being also made into a paste, dried, and ground. The two powders are then mixed together, adding of sulphate of lime eight times the weight of the barytes.

HISTORY.

CHAPTER XX.

THE FEUDAL AGE OF EUROPE.

The observations contained in the following chapter, relate to the same territories as those that formed the scene of the institutions described in last chapter, with the addition towards the close of the period, of Spain on the south; and the localities now occupied by Denmark, Sweden, Norway, and Iceland, on the north. The frontier line on the east, between the Alps and the Danube, is a little farther to the eastward; and the British Isles, on the west, come more prominently into notice.

The period occupied by the gradual developement of the civil institutions which are to be discussed in this chapter, extends from the death of Charlemagne in A. D. 814, to the commencement of Luther's mission about the year 1519. The same arrangement as in last chapter shall be observed: detailing, first, the progress of civil institutions; second, the progress of church organization; third, the peculiarities of moral and intellectual character evolved in society, under the influence of the civil and ecclesiastical authorities.

I. The first point in our enquiries regarding the civil organization of Europe during this period, is to ascertain in whom the sovereign authority was vested, and what was the nature and extent of that sovereign authority. After the death of Charlemagne, the empire, which his strong hand with difficulty held together, tottered under the impotent sway of his successors; and with the extinction of his legitimate descendants, it expired altogether. The East Franks, that is the inhabitants of the provinces of the Frankish empire east of the Rhine, elected Arnulph, an illegitimate brother of Charles the Gross, for their sovereign. The West Franks elected Count Ado, of Pavis, to be their king. In Italy the majority supported Count Guido of Speletor, and in 891 the Pope crowned him emperor. It is not necessary at present to trace the events in consequence of which the permanent erection of three great independent countries followed from this division: it is sufficient to note that from this time, Italy, France, and Germany must be considered as independent states. But the division did not stop here. We have already seen the process by which the personal followers of the warrior leaders among the Germanic tribes, rewarded in the new kingdoms, not by gifts of moveable property, but by the assignment of the use of portions of land so long as they continued faithful, had laid the foundations of the feudal system, and were becoming insensibly the most powerful body in the kingdoms. A skilful commander leaving a son of ripe years and military ability, that son naturally stepped into the extensive feudal holdings of his father, as well as his allodial or freehold property; and when (as was almost always the case) that father held the office of count (graf); or frontier-count (mark-graf); or general (Herzag); the son also succeeded to the office. Thus were established families, regarding themselves as entitled to hereditary rank and office; and thus did men come to regard feudal tenures as equally permanent with allodial property; the possession of allodial property, as implying equally with that of feudal, allegiance to the head of the state; and the tenure of large properties of either or both kinds as inseparable from the tenure of state offices to which their holders were in the habit of succeeding at the same time. As the wealth and power of this class increased, so did its ambition; and as this increase was frequently co-temporary with degeneracy and pauperism on the part of the reigning race, an aspiration after independent sovereignty was encouraged in the breasts of the most powerful. The whole history is, in so far as the sovereigns are concerned, a series of attempts on the part of brave and wealthy nobles to found and extend such feudal kingdoms. This tendency was increased by the irruption of the last Germanic tribe that obtained permanent settlements in Europe as conquerors—the Normans. Under their name are included hordes of marine adventurers, collected from the desperadoes of every Germanic tribe; but the most noted in history are the families of Rollo and Robert Guiscard. The former obtained extensive settlements in France: proceeding from which they united under one sceptre the whole of the lands formerly divided among the petty kings of the Saxon Heptarchy. Availing themselves of their power as kings of England, and their possessions in France, they carried on for centuries a struggle for the crown of the latter kingdom; but were ultimately obliged to content themselves with their island domains. The warriors entered the Mediterranean, and being regarded by the Byzantine emperors as a counterpoise to the Arabs, and Lombards were encouraged to settle in Sicily, so early as 1029. In 1046 they entered into alliance with the German emperor. And seven years later Robert Guiscard deemed it wiser to hold all that he had conquered in Apulia, and all that he intended to conquer in Calabria and Sicily, as a fief from the Pope. During the latter centuries of this period the mountain chiefs of the Gothic race in Spain gradually reconquered the richer portions of that land from the Arabs, and erected them into independent kingdoms. Those were finally united in the hands of Ferdinand and Isabella, and after them in their successor, with whose accession to the imperial dignity by the title of Charles V, as cotemporary with the commencement of Luther's public mission, this period terminates. Such was the nature of the sovereign authority during this period: precarious in its possession and extent, but uniform in its character. The sovereign was he who possessed territories not held of any over-land, and who had vassals holding of him within these territories. He might hold other territories as a vassal, without hurting his character as sovereign. A kingdom was in those days the territories possessed by a king as over-land. Hence we find the boundaries of kingdoms, and the constitution which obtained within them, constantly shifting and fluctuating. Amid this chaos of precarious feudal sovereignties, some great monarchies by degrees struck root and assumed definite limits. Among these at the close of this period we can enumerate—Spain, France, and England. In Italy, the king of Naples, the Pope, and several northern princes, were essentially sovereign and independent. So within the limits of the German empire were the Dukes of Burgundy, Lorraine, Saxony, and others.

Notwithstanding this subdivision and incessant shifting of the sovereign power, the developement of civil institutions throughout the European territories was characterised by a marvellous uniformity. The cause was this:—In Europe there were only two main ingredients of society:—The Romans and Romanised Provincials, and the Germanic race. The successive conquests and reconquests of one Germanic race over and from another, had introduced into every province all the different modifications of German law as personal laws. Under the Frankish monarchs or their predecessors, these various laws had, in many instances, been reduced to the form of written codes. The only class of society, whose members were competent to such a task, were the clergy: trained in the Roman circle of instruction, in the almost exclusive use of the Latin tongue, and living according to the prescripts of the Roman law. It was natural under these circumstances, that all the Germanic laws should, in the hands of such redactors, be cast in one common mould, and that a Roman one. Accordingly we find their family-resemblance to each other increased in the written collections, and much law of Roman origin engrafted upon them. In addition to the effects of this assimilating process came two other influences:—1st. The form of the legal tribunals was throughout the whole of the Roman Teutonic states materially the same:—in the municipalities, the Scabini or Schöffen; in the rural districts, the local officers of the Crown; and with an appeal in both cases to the royal court. The decisions by one and the same court, although at times professedly adapted to different systems of law, could not fail to result in an *amalgam* of the whole into one more comprehensive system. 2d. The different races by living together would acquire a community of feeling which would make them cling with jealousy to separate laws, at the same time that the confusion and uncertainty arising from so many conflicting systems would come to be more acutely felt. The combined influence of those two facts produced the gradual and imperceptible decay of personal, and the substitution of territorial laws. Thus, throughout Europe a system of law essentially the same came to be insensibly administered in all the local tribunals.

II. The advance of the church in organization and concentration of power was more decided during this period than was that of the state. As the descendants of Charlemagne became more and more incapable, the papal assertion of temporal territorial sovereignty, already alluded to in last chapter, began to be more boldly advanced on the part of the Popes. The final division of the empire, and the perpetuation of shadows of elective emperors in Rome and Germany, greatly increased the influence of the Popes. In the case of narrowly contested elections—and almost all elections were such—the Pope, in whom by the consent of all resided the right of crowning the new emperor, could materially influence the election, by throwing his weight into one or the other scale, and thus he obtained frequent opportunities of extorting reluctant concessions from anxious candidates. The arrangement by which Robert Guiscard in 1053, agreed to hold Apulia, Calabria, and Sicily, as a fief of the holy see, contributed much to strengthen the authority of the Pope; and about the same time a system of

policy was commenced, which more than anything else contributed to lend consistency and energy to the Court of Rome.

The author of this system was the daring and intrepid prelate who, from the year 1056 to the year 1073, as Archdeacon Hildebrand, and from the year 1073 to the year 1086, as Pope Gregory VII, wielded the destinies of the Romish hierarchy. The first step of Hildebrand was to organize the mode of electing the Head of the Western Christian world, in such a manner as should insure the observance of a permanent system of policy. So long as the Bishop of Rome continued to be chosen like other bishops by the acclaim of his flock, the laity had a hold of him, and schisms might be occasioned by powerful prelates resenting the concessions made to them at the expense of the Church. Hildebrand had sufficient influence to carry through a new arrangement, in virtue of which the Pope has ever since been elected by the conclave of seventy cardinals, and from among their number. This conclave acts as the Consistorium or senate of the Pope it has elected; and the vacancies which occur in the body are supplied by the appointment of the Pope upon the Cardinals' nomination. By this arrangement the supreme power of the Church was in reality vested in the Conclave. That body elected all new members, and of course only elected such as the majority had reason to know were well affected to their policy, and able to promote it. The Pope, the ostensible head, was chosen for similar reasons by this self-elected body. The Pope and his conclave claimed the right, if not of nominating, yet of confirming all bishops and other prelates of the Catholic church wherever scattered. In addition to the Bishops established in dioceses of countries in which Christianity was professed and established, the Pope and conclave now habitually appointed titular bishops *in partibus infidelium*—missionaries sent out to endeavour, by collecting and establishing churches in yet unconnected districts, to extend the sway of Rome. An appeal lay from the decisions of all church courts, wherever situated, to the Roman Court; and that body also arrogated a right of censure of the clergy's morals and conduct, of reprimand and suspension. In addition to these claims came that of withdrawing the clergy from the secular jurisdiction. Thus was a head secured for the church—in the self-elected conclave—of which the vigour should be constantly preserved by a continual infusion of new members; while any change in its policy was guarded against by the care which the majority took only to admit trust-worthy persons. The provincial clergy were reconciled to the usurpation of this body by the increased importance it gave them, by vindicating their independence of the laity. The submission of the ambitious was assured by the immense amount of patronage exercised by Rome, and its liberality in rewarding its partisans. Another means by which the conclave sought to corroborate its authority was by withdrawing the friars or regular clergy from the controul of the bishop, and keeping them under the immediate superintendence of Rome. By this means a division of interest was kept up among the provincial clergy, of which the Pope and his council skilfully availed themselves to strengthen the allegiance of both.

By these steps the Romish church became an organized corporation, extending its ramifications into every district of Europe. Having succeeded in asserting its independence of the secular power, it not unnaturally went a step further and sought to claim at least a paternal authority over it. Two suns shine not in one hemisphere, and two independent co-ordinate authorities in one society is still more contradictory to the laws of nature. The superior organization of the church—the superior learning of its members—the ever-fresh supply of talent pouring into it—rendered it more than a match for the herd of feudal sovereigns. Its power went on extending and extending, and would have subjected them all, but for other elements at work in society destined to be alike fatal to both the contending powers.

Before proceeding to the third head which we marked out for consideration, and which must be reserved for next chapter, some further reflections are requisite regarding the two organized powers we have been contemplating. Busied in extending and confirming these rights, the attention of the church of Rome came to be almost exclusively concentrated upon the temporalities of the church. In the provinces, haughty and illiterate nobles were allowed to press into the dignified stations of the church, with a view to secure their alliance. The presence of the prelates at court was necessary, even when they were not spurred by secular ambition, in order to defend and maintain their proprietory rights as great feudatories of the realm. Amid such loads of secular business—and with such constant influxes of unpurified secular spirit—the church became in time thoroughly and inveterately secularised. There were not, in truth, a spiritual and a secular organization in Europe: there were only two great rival secular powers; and so busy were these rivals in extending their respective powers and striving to get the upper-hand of each other, that they had little time left to attend to the real duties of civil governors; even though their faulty and partial organization—owing to the priestly bias of the one, and the military bias of the other—had been adequate to the task.

In reality, therefore, the people were left pretty much to govern themselves; and in the exercise of this privilege, and in preparing themselves for a more avowed and unequivocal use of it, two institutions which were silently maturing during this period were mainly instrumental: the free towns, and the great law schools.

In regard to the first, our attention has been repeatedly directed to the developement of the municipal constitution, its universality under the Roman empire, and its survival in Italy, Spain, Gaul, and Germany west of the Rhine; and to the substitution of Germanic dynasties for the Western Emperors. As the new sovereigns, in general less skilful in the art of government than the old, and less jealous of their authority, interfered less in matters of local jurisdiction, the importance of the Deucrions in Italy, and of the Deucrions and dependants in Gaul, Spain, and Germany west of the Rhine, increased. With the practice of self-government, men's consciousness of their own strength revived, and with it a more hopeful spirit of enterprise. With all sovereigns over districts not included within the Roman frontiers, and where consequently such towns did not exist, a frequent means of encouraging the cultivation of the land, was to assemble men in communities, and allot to them a certain extent of territory within which they might disperse as they pleased. The organization of those communities was naturally on the footing of the old Roman municipalities or of the old German settlements, which had much in common. Analogous communities grew up spontaneously around the seats of powerful prelates or secular nobles. As these towns grew in wealth they grew likewise in boldness. The multitude of their citizens and their fortifications inspired them with courage. When the oppressions of the neighbouring lands became too great to be endured, they ventured to shut their gates against them. When a feeble sovereign exposed the country to invasion, in the absence of the feudal militia, they ventured to defend themselves. From this they advanced so far as to form alliances offensive and defensive with each other. They made their importance be felt. Their alliance was courted by sovereigns against their unruly nobles, by nobles against oppressive sovereigns. The institutions of these towns were republican, and within their walls a spirit was nursed which achieved much, even during the present period, and was destined to achieve still more in that which was to come.

To proceed to the schools of law: the first of these institutions that attained maturity, and the most important of all, was that of Bologna. How far back instruction in the Roman law may have been dispensed in that city, it is impossible to say. The earliest notices that have come down to us relate to the middle of the twelfth century. We do not find even at that time any organization of what can properly be called a university. We find merely distinguished teachers and multitudes of scholars attracted by them. The explanation of this is simple: the old fable of the accidental discovery of a copy of the Pandects during the previous century points to it. The Roman law was preserved throughout the rest of Europe by tradition of the tribunals, or by abstracts and compilations, which we still possess, made under the auspices of Germanic sovereigns. But Ravenna, Rome, and the whole of the south of Italy, it will be remembered, was re-conquered to the eastern empire under Justinian. It was that emperor who made the compilation of Roman Jurisprudence, consisting of the Institutions, Pandects, and Codex, to which we are indebted for our knowledge of by far the greater portion of Roman law. In Ravenna and the adjoining territory it was therefore natural that Justinian's compilation should be preserved although it had (not exactly as the legend has it, been forgotten, but) remained unknown to the other European territories. There is nothing very surprising in finding the Pandects at Bologna in the twelfth century; and as at that time greater wealth and activity was bringing about every where a revival of intellectual pursuits, it was natural that expounders of that collection of law should also be found there. The reputation of the teachers attracted students; the success in after life of their students attracted more. With increasing commerce the relations and transactions of society were becoming more complicated, and with this complication came a demand for more learned languages. Some of the emperors, out of gratitude for services done them by the jurists, extended these privileges. Other cities aspired to rival Bologna by instituting or encouraging the institution of similar schools. These *studia*, as they were called, received in time constitutions borrowed from the guilds or corporations, which had been

established with a view to promote mere mechanical occupations. The term *Universitas* was not conferred upon these schools, as some over-hasty etymologists have conceived, in order to express that their tuition embraced the whole range of science. We find the title applied frequently in the middle ages to special schools of a single science. Thus we have the universities of law and universities of theology. The truth is, the title indicated not the aggregate or Universitas of what was taught, but the aggregate, or *Universitas*, or corporation of the persons who were taught. It is painful to reveal the ignoble original of a title which Oxford and Cambridge would fain arrogate to themselves exclusively, and which others—*dii minores gentium*—the pocket universities, more properly colleges, of Scotland assume with such complacency. But the truth will out—the term *Universitas* designated originally nothing more than a corporation; and we read repeatedly in the records of the early middle ages of universities of tailors. The members of the learned universities were subdivided in the same manner as those of the mechanical universities into apprentices, journeymen, and masters; or, as the corresponding grades were called in the former class of students, Laureates, and Doctors or Teachers. The title of Doctor, from an Italian University, came soon to pass current as a warrant or certificate of capacity in all courts throughout Europe. The ecclesiastical lawyers began to grow jealous of the eclat which attached through this means to the secular lawyers, and opposition lectures were got up, and an opposition body of Canon Law compiled, in clear imitation of the Institutions, Pandects and Codex. From this event we date the plural form in the title of Doctor of Laws, or doctor of both laws (that is, civil as well as canon), as some countries have it. Not only was the uniformity of the leading principles of law throughout Europe, and the vagueness attaching to the form in which law everywhere existed, (mere consuetudinary law, or heaps of decisions,) favourable to the reception of these Doctors everywhere; the universal validity of the title *Notarius*, or Notary, the bestowal of which was long held to be the exclusive privilege of the Pope or Emperor, paved the way for them. In all the free towns or municipalities throughout Europe, the services of these Doctors were earnestly solicited and highly remunerated. In the church courts also, the doctors were certain of promotion. Nobles and sovereigns were anxious to obtain their services; and even the more ambitious of the young nobility flocked to Italy to acquire knowledge which opened new paths of ambition. Finally, independent sovereigns instituted seminaries which rivalled that of Bologna; and thus the tribunals of Europe were furnished with judges more competent to the perplexing questions of law arising out of the progress of society. Law and its dispensers thus attained to a degree of respect, I may say veneration, beyond what was previously paid to them. Men were taught practically to feel that they had rights, and that there could be no more dignified position than that of a man calmly and fearlessly asserting his rights in the face of a superior wealth and power. The tribunals, and such as worthily filled them, succeeded to a great portion of the esteem and deference paid in early times to the church—after the tribunals of Rome had by excess of corruption forfeited respect, and before the rude warrior monarchs of the Germanic race had learned to lay aside the conqueror.

DESCRIPTION AND USE OF THE MECHANIC'S SLIDE-RULE.

ARTICLE I.

The slide-rule is an instrument for facilitating calculations connected with various mechanical employments, and is extensively useful, particularly for engineers and others engaged in the mensuration of wood, stone, glass, painting, plastering, and so forth.

The slide-rule is commonly constructed on the reverse of one of the legs of a two-feet rule, and is consequently one foot long. The slide itself is a slip of wood or brass, more commonly the latter, sliding in a dove-tail groove formed on the leg. Hence the name of the rule.

The surface of the slide, and the contiguous parts of the surface of the rule, have four distinct ranges or lines of divisions inscribed on them, called *lines of numbers*. These lines are distinguished by the first four letters of the alphabet A, B, C, D, which are stamped opposite them on the surface, towards the right hand. The first and fourth lines, A and D, are inscribed on the surface of the rule; and the second and third, B and C, on the surface of the slide. It is obvious, then, that by shifting the slide one way or another, any graduation upon its scales may be placed in any position relative to the scales A or D; and by a simple operation of this kind all calculations on the slide-rule are performed. The line D is usually designated the *girt-line*, from its use in timber-measuring. The scales fall half-an-inch short of the length of the rule, at each end; they are consequently just eleven inches long.

Notation of the Slide-Rule.

On examining the scales, we find that three of them, A, B, and C, are exactly the same in their graduations and in the numbers attached to the graduating lines. Further, each scale is divided into two equal and similar series of parts; that is, the one-half is an exact repetition of the other; and the numbers attached to them, beginning at the left hand, from 1 to 10, are likewise repeated. Hence the lines A, B, and C, are called double lines of numbers. The divisions on the fourth line D, are not repeated as on the others, but run uninterruptedly on from left to right, and are numbered from 4 to 40. The magnitude of any one of these divisions, it may be seen, is double that of the corresponding division in any of the other lines. The division 5, 6, for example, on the line D, has double the extent of the division 5, 6, on the line A, B, or C. From this, it is clear that the same law regulates the graduations on all the lines. The line D, we have said, begins at 4 and ends at 40; the three first divisions being omitted in order that the 12th division may be situated as near as possible to the middle of the scale: by this means, the content of a solid is, in general, found at one operation.

The principle upon which the scales of the slide-rule are graduated depends simply upon the relation which subsists between natural numbers and their logarithms, namely, that if a series of numbers be in geometrical proportion, their logarithms are in arithmetical proportion. For example, let us take, for simplicity the geometrical proportion,

$$1 : 10 :: 100 : 1000,$$

the logarithms of these numbers will form the arithmetical proportion

$$0 : 1 :: 2 : 3.$$

From which it is obvious that, in logarithms, the difference between the first and second terms of a proportion is equal to the difference between the third and fourth;

$$\text{for } 1 - 0 = 1, \text{ and } 3 - 2 = 1.$$

We shall now part with this illustration of the principle, and proceed to the scales. Confining our attention, for the present, to the scales A, B, and C, it will facilitate our acquiring a clear notion of the nature of the graduation if we lay open before us a table of the logarithms of whole numbers from 1 to 100, which is to be had in any work on logarithms. The *figures* on the scales being the natural numbers representing magnitudes of any kind, the *distances*, reckoning from left to right, at which they stand from the beginning of the scale, represent, by their magnitude, the logarithms of these numbers. In the first place, the logarithm of 1 is 0, and, therefore, the position of the natural number, 1, is at the beginning of the scale. Again, the logarithm of 10 is 1, as we find from the table of logarithms; the logarithms, therefore, of the intermediate numbers between 1 and 10, must necessarily be greater than 0 and less than 1, and in fact they are expressed in the table in the form of decimal fractions. It is clear, then, that if we take the half-length of the scale, between the first and the second 1, to represent the logarithm of 10, the logarithmic distances, as they may be called, of the intermediate numbers, 2, 3, 4, &c., from the beginning of the scale, will be in the proportion of the fractional numbers referred to: thus, the logarithm of 2 is, to take it roundly, 0·3, or about $\frac{3}{10}$ths of the whole distance, which we find on trial to be the case; the logarithm of 3 is 0·48 nearly, or nearly $\frac{1}{2}$ of the whole distance; the logarithm of 4 is about 0·6, or double that of 2, which we find to be represented by the distances on the scale; the logarithms of the other distances below 10 we find, on similar rough trials, to be represented by the distances at which the numbers stand from the beginning of the scale.

Having by this means acquired a familiarity with the *logarithmic* distances of the *natural* numbers from 1 to 10, on the scale, we can readily see the extension of the same principle of setting off distances, in the subdivision of those logarithmic spaces. Each of these spaces, we observe, is divided into 10 smaller spaces; and the first three spaces, from 1 to 4, are still further subdivided, the subdivision not being extended into the other spaces, simply to prevent confusion. The subdivision of each space into tens is effected according to the same law of logarithms by which the primary divisions are regulated; and these decimal subdivisions represent the logarithmic distances of whole numbers with frac-

tional parts. For example, the logarithmic distance of the number 4·3, terminates between the primary graduations 4 and 5, at the end of the third subdivision reckoning from 4; in like manner, the logarithmic distance of the number 6·5 terminates on the fifth graduation past the line marked 6. By this subdivision, then, we see that arithmetical operations, performed by means of the scales, are rendered susceptible of greater accuracy, as a number containing a decimal fraction of one figure, can always be exactly located. Now, it is with the view of extending this accuracy, that the spaces from 1 to 4 are still more subdivided. The spaces 2,3, and 3,4 being divided first into ten parts, each of these is divided into two, representing half a tenth-part, or ·05; so that, had we to locate the number 2·75, we would reckon first from the primary division 2, to the 7th principal subdivision, which would represent 2·7, and then to the secondary subdivision beyond this, which would represent 2·75 as desired. Finally, the decimal subdivisions of the space 1,2, are further subdivided into 5 spaces; this conduces to still greater accuracy in locating numbers, as the value of each of these spaces is but ·02. To locate the number 1·36, we reckon from 1 to the third subdivision, which represents 1·3; and then, as the interval between 1·3 and 1·4 is divided into five parts, each of these parts represents ·02, or one-fifth of ·1; consequently three of these must be included, as ·06 is three-fifths of ·1.

We have said that the subdivisions of the scale between the second 1 and the third 1, are merely repetitions of those between the first 1 and the second 1; and therefore the foregoing illustrations apply equally to both. Further, we have been reasoning on the supposition that the 1 at the beginning of the scale is taken as simply 1, the 1 at the middle representing 10. Now, according to the nature of logarithms, the scale will be equally applicable to purposes of arithmetic, whether the 1 at the beginning of the scale be taken as simply 1, or as 1 ten, or 1 hundred, or 1 thousand, or 1 unit of any other denomination, provided the second and third 1 on the scale, be reckoned respectively ten times, and a hundred times greater; and the intermediate values to correspond. If the 1 at the beginning of the line denotes 10, for instance, then the 1 at the middle denotes 100, and the 1 at the end represents 1000; the primary graduations 2, 3, 4, &c., between the first and the second 1, will count 20, 30, 40, &c., and those between the second and the third 1, will count 200, 300, 400, &c.; and the subdivisions will be estimated accordingly. Hence, it may be observed, that the numbers in the second half of the scale, when taken in connection with the first half, are ten times the value of the corresponding numbers in this first half; and hence, the following general rule for locating, or finding the logarithmic distance of any proposed number, will be evident:—

Rule.—Among the primary graduations of the first half of the scale, take the figure of the highest denomination in the proposed number; among the principle intermediate graduations, take that which numbers the same as the figure of the second highest denomination; and for the remaining figures of the number, if there be any, take a proportional part of the space between the graduation last arrived at, and the next principal intermediate graduation. If the subdivisions of the scale be not minute enough for the last step, the space must be taken by estimation.

Examples.—Required the point representing 53. Here the 1 at the beginning of the scale may be reckoned 10; accordingly the primary graduation 5 represents 50; and the third graduation beyond this will represent 53. The same point would represent also 530, 5300, &c., if the 1 at the beginning be assumed to be 100, 1000, &c. to correspond.

Required the point representing 164. The 1 at the beginning of the scale being taken to represent 100, the additional value of 64 must be found by reckoning forward; not to the sixth primary division, however, for it now represents 600, but to the sixth intermediate principal division between the points marked 1 and 2. This point, then, represents 160; and since the interval between 160 and 170 is subdivided into 5 parts of equal values, each of these parts represents 2, or one-fifth of 10; and as the unit figure of the proposed number is 4, by reckoning forward two subdivisions, we arrive at the point representing the number 164.

In this example, we set out with assuming the value of the 1 at the beginning of the scale equal to 100; we might have assumed it equal to 10, and by doing so, the *second* 1 would represent 100, between which and the third 1, therefore, the locating of the number is to be effected exactly as it was done in the first half. The necessity of attributing suitable values to the initial points of the scale is rendered apparent, when we consider that had we assumed in the preceding instance, the first 1 to be simply 1, the third 1 would have been no more than 100; when of course the proposed number could not have been located.

Required the point representing 547. In this, as in the last example, the first 1 may be assumed either as 10 or as 100. Take it at 100; then the primary division 5 will represent 500, and the remaining 47 will be between 5 and 6; the fourth subdivision, reckoning from 5, will be 540; the space between the fourth and fifth subdivisions being supposed divided into 10 parts, the seventh of these divisions will represent the complete number 547. This last step, owing to the minuteness of the space, can yield no more than an approximation to the true point; and without really attempting the minute division of the space, we may at once take three-fourths of the space to find the point required—seeing that 7 is nearly three-fourths of 10.

Required the point representing 1378. The 1 at the beginning of the line being taken as 1000, the third primary division is 1300, the seventh principal subdivision is 1370; we have yet to take in the unit figure 8, for which purpose, we have in the first place the secondary subdivision, following the seventh just now arrived at, to represent 5, added to which three-fifths, by estimation, of the next sub-space will give the point representing 1378.

The place of 1806 is required. The 1 at the beginning or middle representing 1000, the 8th primary division represents 1800; the first subdivision being 10 additional, six-tenths of the space being taken by estimation, will give the place of the proposed number.

The place of 23·49 is required. Taking the first 1 as 10, the primary division 2 is 20, and the third principal subdivision is 23; the space between this and the fourth principal subdivision being 1, we must just approximate to the point for 23·49. Now 49 is nearly ·5 or half of 1; therefore the secondary subdivision following the point for 23, will be very nearly the point required.

The study of these examples will render the student familiar with the method of locating numbers on the slide-rule. If these be clearly understood, there can be no difficulty in understanding the fourth scale D, as this scale is similarly divided.

Proportion by the Slide-Rule.

We have already stated the principle on which the slide-rule is constructed, namely, that, in logarithms, the difference between the first and second terms of a proportion is equal to the difference between the third and fourth terms. Let us take, for example, the natural numbers 2, 3, 6, and 9, which constitute a proportion, thus · 2 : 3 : : 6 : 9.

Then, according to the principle now stated, the difference of the logarithmic distances of the first two is equal to the difference of those of the last two; that is, the space 2, 3, on the scale, is equal to the space 6, 9. This can at once be verified by the application of the compasses. The numbers 4 and 6 also are in the same ratio, and accordingly we find that the space 4, 6, is likewise equal to the space 2, 3, and so on.

If, now, the slide be shifted towards the right, until 2 on B is brought exactly opposite 3 on A, it is clear that the slide has been shifted through a space equal to 2, 3, or to 6, 9, and that 6 on B will also stand opposite 9 on A. Supposing, then, that we had the three given numbers 2, 3, 6, and that a fourth proportional to these three had been required, we had only to shift the slide till 2 on B was set against 3 on A; and opposite 6 on B, we would have found 9 on A for the fourth term required. This simple case elucidates the whole mystery of the slide-rule, as far as the operations of proportion, multiplication, and division are concerned; and from what has been said, the following rule for proportion is derived. Though an account of the method of practically applying proportion to the solution of questions, belongs rather to a treatise on arithmetic, we shall prefix brief directions which may *generally* be followed for *stating* the proportion previous to working it on the slide.

Rule.—In stating the question, the first and second terms are to be of the same name, and the third term will necessarily be of the same name as the result which is required. Let, therefore, that term which is of the same name as the required one, be placed as the third term of the proportion. Then consider from the nature of the question, whether the required term is to be greater or less than the third term. If it is to be greater, the least of the other two terms is to be placed as the first term of the proportion, and the remaining one as the middle term; but if it ought to be less, the greater of the other two terms is to be placed first, and the other in the middle. Having thus stated the proportion, set the first term on B to the second on A; then opposite the third term on B is the fourth term on A, which is the quantity required.

Examples.—If 4 cwt. cost £28, what will 14 cwt. cost? The stating of the proportion is evidently thus,

4 : 14 : : 28 :

Therefore set 4 on B against 14 on A; against 28 on B we find 98 on A; the price of 14 cwt. is then £98. In working this problem, the first 1 on the scale B must be taken as 1, which indeed must always be done when the first term of the proportion is below 10; the first 1 on A, however, may be taken either as 1 or as 10. If it be taken as 1, the fourth term, 98, will be found near the other extremity of the scale, where the third 1 counts 100; and supposing that the fourth term had exceeded 100, the first 1 must necessarily have been taken as 10 at least.

If 7 yards of muslin cost £1, 3*s.*, how many yards may be had for £2, 17*s.*?

23*s.* : 57*s.* : : 7 :

Set 23 on B, to 57 on A; then opposite to 7 on B will be found 17·3 on A, the number required. If, in this case, the 1 at the beginning of the scales A and B, be taken at 10, it is obvious that the third term 7, will not be found on B. Now considering the first 1 as 1, the middle 1 on both scales will be 10, and we consequently find the two first terms of the proportion in the second halves of the scales, and the third and fourth terms behind them. It is clear, at the same time, that in both views of the case just now stated, the setting of the rule remains the same; therefore, supposing we had taken the first 1 on A and B as 10, it would have been easy to have imagined the second on A and B as 10 likewise, which is really done in the second view above stated, and thus we could have at once located the third term 7 on the first half of the scale B, and found the fourth term, 17·3, on A.

From what has now been explained, the student will perceive that all that is necessary to go correctly to work with the slide-rule is to make sure that, whatever units of value be attached to the commencement of the scales A and B for the setting of the two first terms of a proportion, these values be *increased or diminished in equal proportion* on both scales for the setting of the two last terms, if it be necessary to alter the values at all.

The debts of a bankrupt amounted to £750, and his effects to £400; how much will be recovered for a debt by him of £150?

750 : 150 : : 400 :

Set 750 on B, to 150 on A; then opposite 400 on B is 80 on A, the answer. Here the 1 at the middle of A is taken as 100, and the 1 at the middle of B as 1000. This allows the slide to be set without much shifting.

40 yards of fine cloth were bought for £24; how must it be sold per yard to gain £12 upon the whole? £24 + 12 = £36, is the price at which the whole must be sold. Therefore the stating is

40 : 1 : : 36 :

Here we may take the 1 at the middle of B as 100, and the same 1 on A as 1; then setting 40 on B to 1 on A, opposite 36 on B we find ·9 or £$\frac{9}{10}$ on A, which is equal to 18 shillings. If we had stated the proportion thus

40 : 36 : : 1 :

placing the two large numbers together, the shift of the slide in setting would have been very small, and opposite 1 on B we should have found 9 as before. If, again, the answer had been wanted directly in shillings, then 36 × 20 = 720 shillings, and

40 : 720 : : 1 :

Here we see at once, 40 and 720 are in the same ratio as 4 and 72; then setting 4 on B to 72 on A, we find 18 shillings on A opposite 1 on B. In this case, in setting the first two terms, we suppose the first 1 on B equal to 1, and that on A equal to 10; therefore opposite 1 on B, we find 18 on A; or it is the same thing if we take the middle 1 on B as 1, and that on A as 10.

How much money at 3½ per cent. will yield as much interest, as £490 at 4 per cent.?

3½ : 4 : : 490 : therefore set 3½ on B to 4 on A, then against 490 on B is £560 on A.

A ship is purchased for £1200, required the value of that person's share who holds three-eighths?

8 : 3 : : 1200 :, set 8 on B to 3 on A, then against 1200 on B is £450 on A.

If the breadth of a piece of wood is 9 inches, what length is necessary to make a square foot?

9 : 12 : : 12 :, set 9 on B to 12 on A, and opposite 12 on B we have 16 inches on A. Or, again, 9 : 144 : : 1 :, now set 9 on B to 144 on A, and we find 16 on A opposite 1 on B.

If the longest end of the beam of a balance be 24 inches, and the shortest 18 inches, what weight suspended at the extremity of the longest arm, will balance 60 lbs on the shortest?

24 : 18 : : 60 : 45 lbs.

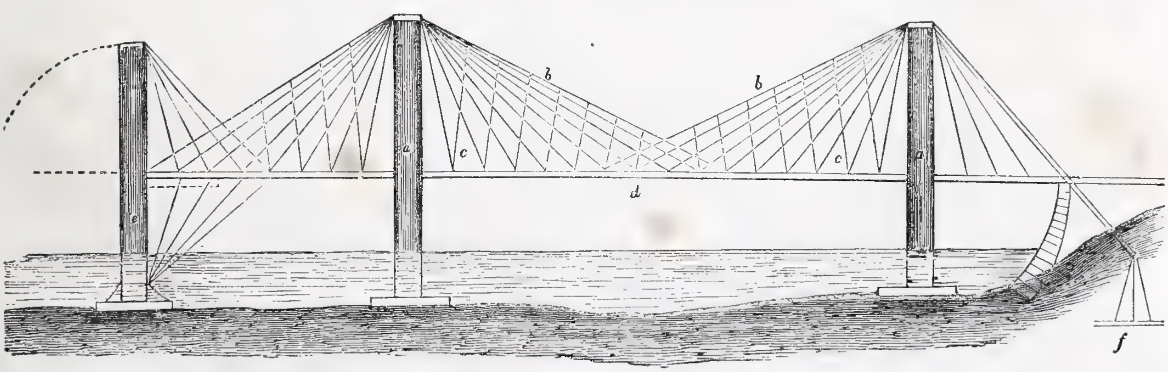
These explanations and examples of the working of questions in proportion by the slide-rule being thoroughly understood, questions in multiplication, division, extraction of the square-root, &c., will be very easily managed by the slide-rule; and these we shall reserve for a second article.

DRAW-BRIDGE FOR NAVIGABLE RIVERS.

Designed by Jacob Guiser, Engineer, Pennsylvania.

The draw-bridge, designed by Mr. Guiser, of which a sketch is subjoined, is applicable for the crossing of large navigable rivers, without obstructing the traffic. The arrangement may be varied to suit any locality, the pieces may be set and built in deep water without the use of cofferdams, and may be of any height without danger of their giving way by supernal pressure. By building them to a height of 400 feet, they will suspend a roadway with safety over spans from 300 to 600 feet; the roadway can be suspended at any height desired, commonly, so that steamers, schooners, &c., may pass underneath with ease; and for large shipping, single or double draw-bridges may be constructed, either in the middle or alongside the shore. The roadway may be paved, and the small balance of exposed timber covered with sheet-iron, so that the bridge will be fire-proof. But the whole platform might well enough be altogether constructed of iron, if desired. In all cases the system of framing is the same.

Fig. 1.—Elevation of one-half of the Bridge.—Scale, $\frac{7}{8}$ths inch to 100 Feet.



Description.—Fig. 1 represents a side view of one-half of the bridge; fig. 2 an end view of one of the piers, *a*; and fig. 3 a ground plan of the same. The piers, *a*, are made or formed of sheet-iron, the inside well filled with hard bricks laid in

good cement: if they are to be sunk into deep water, the base of them may be bolted or spiked down to a timber raft. The plates of sheet-iron must be riveted together water-tight, up to such a height that they may reach out of water when the whole is sunk to its place; the filling up and riveting on of plates of sheet-iron is then continued to the height desired. On the top is set a casting with horns, which receive the loops of suspension rods *b*, of $1\frac{1}{4}$th or $1\frac{3}{8}$th diameter; when these are all on, the horns are hooped together to prevent their separating. The

Fig. 2.

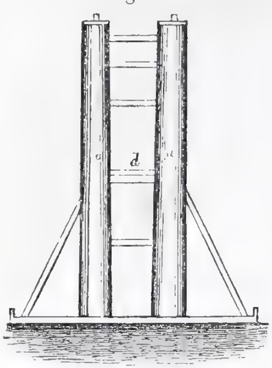
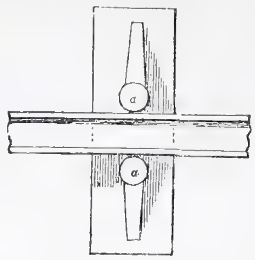


Fig. 3.



roadway is made of a double line of heavy string-pieces, composed of several layers of timbers of between 3 and 4 feet in height by 15 inches in thickness, the whole being bolted together to give a great stiffness to the structure. The suspending-rods correspond with other loops in the string-pieces, and are divided to equal distances and in such numbers that they may be made to stand only one-sixth part of the greatest stress falling on the string pieces. The timber in the roadway should all as much as possible be lengthways with the bridge, and the string pieces particularly must be well fastened to, and behind the abutments, as shown at *f*; the suspending rods *b* are prevented from falling into a curve by the supporting rods *c*, hitched with wire to their sides, and so keeping the triangles in their exact form. The piers *e* contain each a drawbridge, which with its counterweight of 150lbs. surplus, works on fulcrums like the beams in scales; the counterweight is commonly hitched up underneath the roadway by means of chain and small gearing, and when a vessel is to pass it will move very easily and quickly out of the way. For the river Thames, the bridge should be constructed with long and high spans and double drawbridge, to give all sorts of vessels plenty of free play at once. The roadway should in all cases be at such a height that steamers can pass underneath anywhere at highwater with ease; that will also be high enough for schooners. The base of the piers being fastened down to a raft, this must in strong currents be well loaded and surrounded with heavy stones to prevent the surrounding sands being washed away. The suspending rods being welded and finished up to a whole length, must all be tried in a machine to their greatest strength, and divided into the string pieces accordingly, the roadway paved with a composition of stones and cement, and the balance of timber covered with sheet-iron. Very strong and durable bridges for all localities can be built by this method.

WEBB'S ELLIPTOGRAPHIC COMPASS.

The instrument which constitutes the subject of this patent is fitted for tracing elliptical figures, either with ink or pencil; and, by substituting a sharp blade for the pen or pencil, figures of the same form may easily be cut out. The principle on which it is based, rests on that property of the ellipse which is often set off with a slip of paper, by means of the difference of the semi-axes.

Fig. 1 represents a vertical section of this instrument, which is supposed to be working with a drawing-pen. Fig. 5 is a plan, as seen from above.

All the moveable parts of the instrument are placed on a horizontal copper table, *a*, supported on four legs, *a′*, fitted with screws, to admit of being lengthened at pleasure. On this table are two guides, *b*, between which a circular plate, *c*, is moveable, either with a circular or sliding motion, and on which is fixed, by means of a screw, *d*, a vertical rod, *e*, which passes through the table. This rod is attached to the drawing-pen holder, *f*, which is traversed by a horizontal screw, *g*, and this, according as it is turned in the one direction or the other, pushes outward or inward, from or towards the centre of the table, the drawing-pen, *h*, or the pencil-holder, which may be put in its place.

The instrument being thus adjusted, if the guide-rod, *e*, is placed at the exact centre of the circular plate, and this plate be made to turn, it is clear that the drawing-pen will describe the circumference of a circle. But if this guide-rod be fixed to the plate at a point more or less removed from its centre, the figure described will be an ellipse.

To trace one of these figures when the two axes are given, the length of the shorter axis is measured from the centre of the plate, *e*, on the groove which is made in it, and which has divisions engraved upon it. At this point the centre of the rod, *e*, is made fast by means of the screw, *d*. The difference of the two semi-axes of the ellipse is then measured from the centre of the rod, *e*, on the drawing-pen holder, *f*, and, by turning the screw, *g*, the pen-holder is moved in the proper direction. We then have, from the centre of the plate, *c*, to that of the rod, *e*, the length of the small axis, and that of the longer axis, from the centre of the same plate, *c*, to the centre of the drawing-pen. Now, as the rod, *e*, works in a slot, *i*, in the table, made in a direction perpendicular to the line described by the centre of the plate, *c*, which is evidently parallel to

Fig. 1.

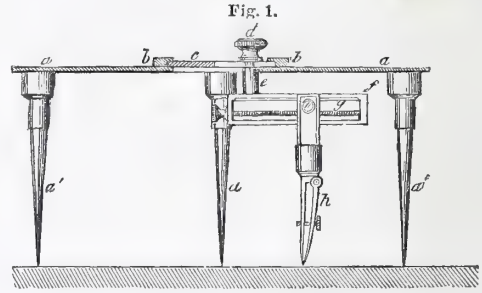
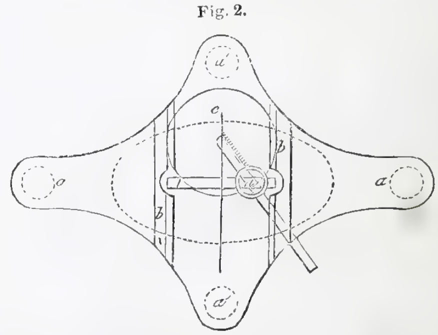


Fig. 2.



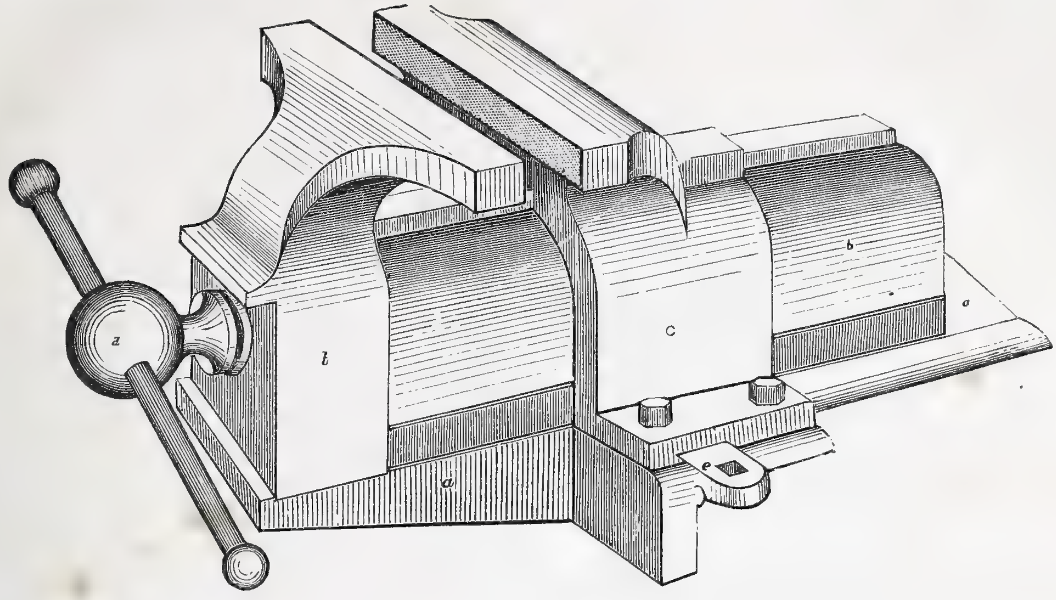
the guides, *b*, the centres of the rod, *e*, and of the plate, *c*, being retained in the axes of the ellipse, it follows that the point of the tracer must describe an exact ellipse.

But to render this instrument of actual use in the arts of design, the table, *a*, is raised on feet, to avoid the necessity of holding the instrument on the paper with the hands; and to be able to trace ellipses on given axes, the feet or legs are adjusted in the direction of the axes themselves, which permits of placing the instrument on given axes with great facility and promptitude.

STIVEN'S PATENT PARALLEL VICE.

This vice is bolted directly to the vice-board by two snugs cast on the sole, *c*, which is flanged on the under side, and

abuts against the edge of the bench. One of the jaws, *b*, is bolted to the sole, and under it the other jaw, *a a*, slides upon the flat surface of the sole. The upper side of the slide, *a*, which is hollow, has a square feather upon it, which corresponds



to a groove in the inside of the fixed jaw-piece, *b*; the slide, *a*, is also furnished with strips along the bottom edges, which likewise slide against the sole-plate, *c*. Thus, the piece, *a*, is held steady, and is moved along the sole by means of the screw and lever, *d e*; this screw, being confined in a collar at the neck, and projecting into the interior of the slide, *a a*, works in a nut attached to the sole-plate. By this means the moveable jaw may be slidden along the sole, and screwed up against the fixed jaw, *b*, holding firmly any object that is placed between them.

The main advantage of this vice consists in the parallel movement of the sliding jaw, which prevents the work being marked. It is also stronger, and likely to be more durable than the common vice, in consequence of the direct action of the screw, and its being completely protected from all dust and filings.

A WATCH WITHOUT A KEY.

By M. Bissen, Paris.

The advantage of being able to dispense with a key in winding up watches, and setting them to the proper time, is incontestable. In fact, the necessity of using this appendage is a cause of frequent repairs. Besides the disadvantage, otherwise very great, of having the key separate from the watch, its movement is less to be depended on, and not so easily kept steady. The square pin for winding up the watch, and that by which the hands are moved, are the two pieces which suffer most, in consequence of the pressure exerted upon them by the key; the former, if this pressure be applied a little obliquely, is apt to get bent, and often breaks; the second rapidly wears in the corners.

A further disadvantage arises from the presence of the two holes by which the key is introduced; it is by them, in fact, that dust finds its way into the works, either coming from the hole of the key or through the joints, or even, when excessive care is used, from the very bit of linen or rag with which the cap is wiped clean.

To obviate these disadvantages, several plans have been suggested, more or less complicated and expensive. The mechanism devised by M. Bissen is, on the contrary, very simple and economical. Moreover, it is well known that flat watches have necessarily the cap and case very thin, so that, in resting or supporting them on the back, they yield, press on the works, and injure the watch. By the modifications which M. Bissen has applied to his keyless watch, the bridges are placed higher, and thus the works are protected.

Fig. 1 represents the mechanism for winding up the watch. A, indicates the bridge of the barrel; B, a toothed wheel placed

Fig. 1.

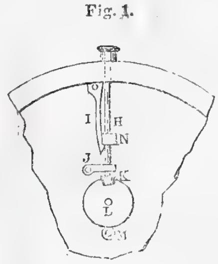


Fig. 2.

under this bridge; C, a rack, performing the part of a catch; D, a spring for keeping the rack in gear with the wheel, B. A steel plate is adjusted to slide on the back of the case, and kept in its place by the curved plate or slip, G. F is a button or knob fixed to the plate, G.

By giving the button, F, a come-and-go movement, the ratch, C, which moves in the same manner, causes the wheel, B, to turn, and by this means the watch is wound up. This movement is very simple, does not complicate the mechanism in any respect, and answers as well as possible the end proposed.

The inventor has it also in view to connect the ratch, C, directly with a small rod, or pin, which it would be sufficient to draw back or push forward. In this case an alternate rectilinear movement would take the place of a circular movement.

Fig. 2 shows the mechanism for setting the watch to the hour. M is a chausee wheel, which is found in all watches;

L, the minute wheel, or an intermediate wheel, according as it is proposed to act directly on the hands or not; K indicates a pinion gearing with the wheel, L; J, a small bridge to sustain the pinion; H is the shaft of the pinion, terminating in a button; and F a spring, to keep the pinion in its place when drawn back or pushed forward.

The figure indicates the mechanism in that position in which it is ready to act. The end of the spring, bearing on the catch, N, prevents the pinion from getting out of its place. It is only necessary to turn the button to the right or left, to move the hands forward or back. The pinion turns, and turns the wheel, L, which again turns M. With this view, the wheel, L, is formed both as a right wheel and a crown wheel; in this case it is so adjusted that its teeth may gear with the wheel, M, below, and with the pinion, K, on its upper side.

When it is not wished to touch the hands, pressure is applied to the button; the pinion sinks so as to quit the teeth; the spring rests on the upper part of the catch, N, to prevent it from moving back, and the wheel, L, is left entirely free.

The knobs or buttons for producing these movements, both for winding up the watch and for setting it to the hour, are placed on each side of the point at which the watch is suspended. One might even use the knob which is placed at that point, for passing through it the rod to work the mechanism.

POWIS AND JAMES' PATENT SLOTTING, GROOVING, & MORTISING MACHINE.

(Patent dated March 10, 1853.)

The principal novelty which distinguishes this machine from others of the same description, consists in the arrangement adopted for giving a vertical motion to the working tool; this motion being derived from a crank or levers actuated by suitable gearing from a continuously revolving shaft. The general construction of the machine will be easily understood from the following description, and a reference to the annexed engravings.

Fig. 1 is a side elevation, fig. 2 a front view, and fig. 3 a back elevation. A A is the framework, which also forms the base for the upper parts of the machine to rest on. The top surface of this framework is planed perfectly true, and has formed upon the V-piece, *a a*, in which the slide, B, is capable of being moved to and fro in a longitudinal direction when acted upon by the hand-wheel, C, keyed upon the spindle, D, which has keyed upon its centre part a pinion, E, shown in dotted lines in fig. 3, which gears into the teeth of a rack, bolted to the under side of the slide, B. By this means the exact longitudinal position of the slide can be regulated so as to bring the wood or other material to be operated upon immediately beneath the action of the cutter. F is another slide, which works transversely in V-grooves, *b b*, upon the slide, B, and is adjusted to the cutter by the hand-wheel, G. H H^1 are two jaws, between which the material to be operated upon is held. The jaw, H, is cast in a piece with the slide, F, while the jaw, H_1, is free to slide backwards and forwards, and is adjusted to the requisite gauge by the screw, I, tapped through a nut in the bracket, K, and turned by the hand-wheel, L. M is an upright frame, the lower portion of which slides in V-grooves, *c c*, on the framework, A, but is retained in its proper position by the screw and nut, *d*, passed through the slot, *e e*. By means of this slot, *e*, the height of the frame, M, can be regulated to adapt it to the stroke of the cutter. N is a vertical shaft which slides up and down in the bearings, O O^1, upon the frame, M. The lower end of this shaft is formed with a socket, in which the working tool is inserted, and then held firm in its place by the screw, *i*. The upper part of the shaft is capped with the T-piece, P, from which are pendent the two rods, Q Q. R is a

Fig. 2.

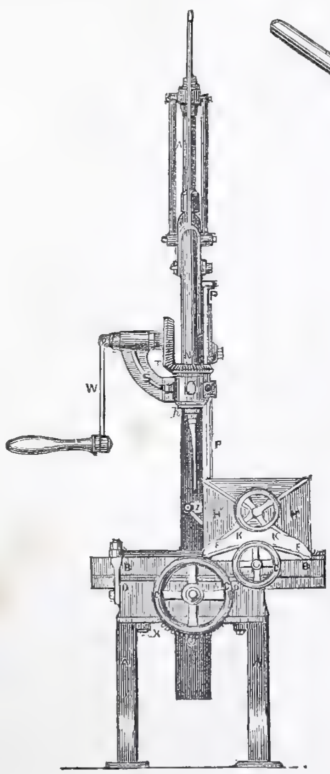


Fig. 1.

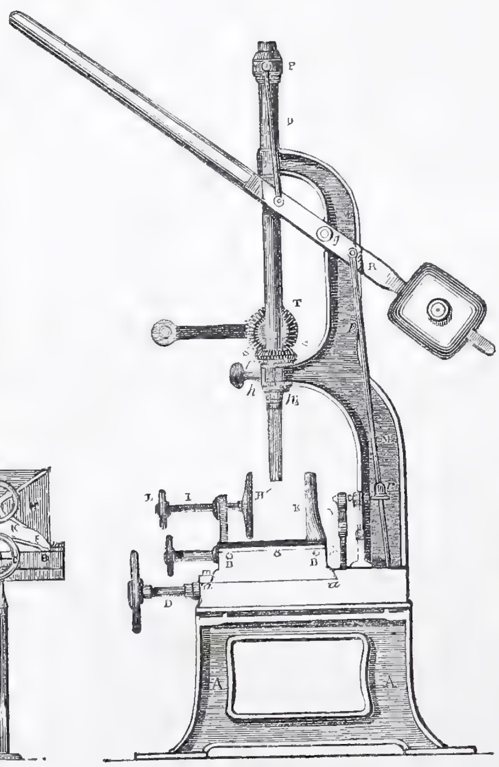
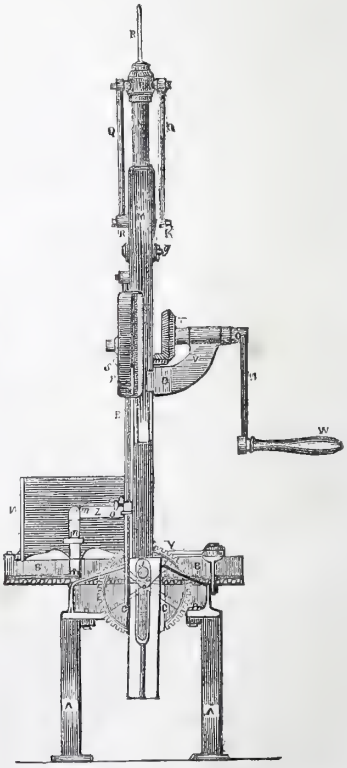


Fig. 3.



counterbalance lever, centred upon the frame, M, at *g*, and connected to the lower ends of the rods, Q Q. S is a bevil pinion, cast in a piece with a hollow tube, *h*, through which the shaft, N, passes. This tube, *h*, is held in the bearings, O^1, and is provided with holes, into which the end of the pin, *f*, takes, so as to hold the cutting-tool firm, and also to enable the tool to be reversed. The bevil-wheel, S, is connected to the shaft by means of a feather and groove. T is a second bevil wheel,

CA

FRANCHOT'S

Fig. 7.

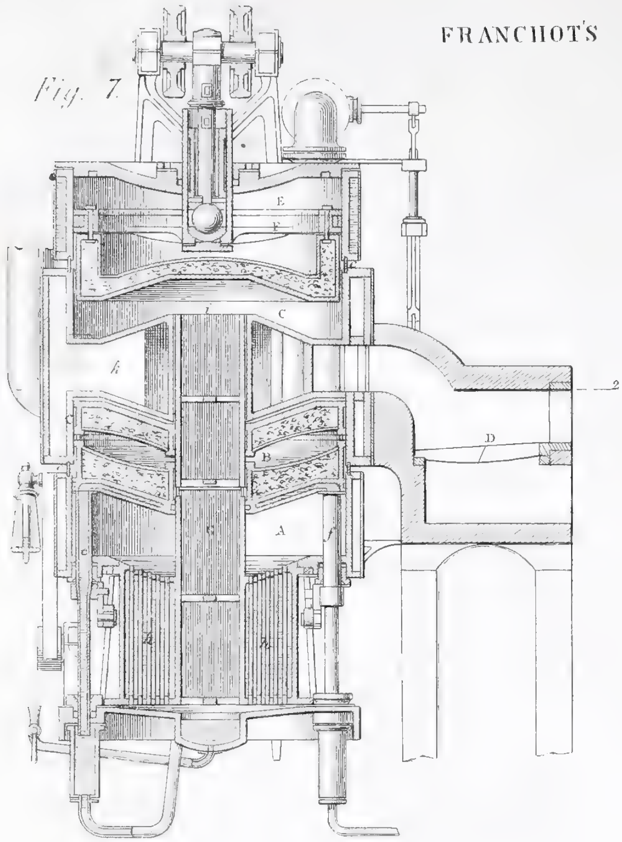
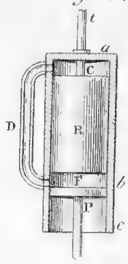
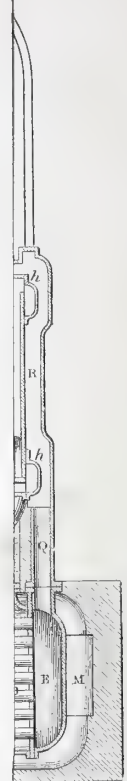


Fig. 6.





STIRL

Fig. 8.

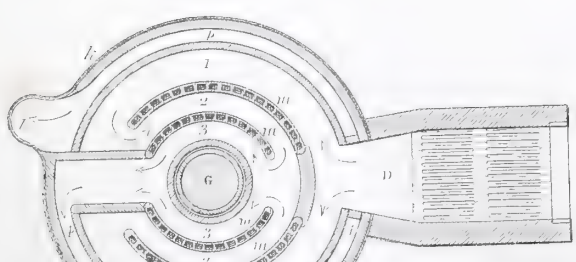
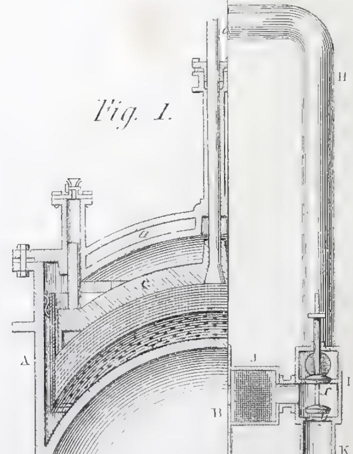


Fig. 1.



upon the shaft, *l*, supported and turning in the bracket, U, bolted to the frame, M. W is a crank-handle for imparting motion to the bevil-wheels, S and T, and through them to the shaft, N, when the machine is to be used for drilling or boring, a tool proper for such purposes being then inserted into the socket in the end of the shaft. X is a spur-wheel upon the spindle, D, and Y a pall, which takes into the teeth of the spur-wheel, D. This pall is centred upon a pin in the end of a bell-crank lever, Z, which is centred at *m* in the bracket, *n*, upon the framework, A. *o* is a lug, projecting from the lever, Z, and *p* a rod pendant from the lever, R, and passed through a hole in the centre of the lug *o*. *r* is a stop or ferrule upon the rod, *p*, which is capable of being retained in any required position on the rod by the pinching screw, *s*. The object of this arrangement is to give to the slide, B, and the material to be operated upon, their proper and regular feed beneath the cutter. *t* is a band of vulcanized india-rubber, which embraces the bracket, *n*, and bell-crank lever, and so acts as a spring to draw back the pall, by which the lever, R, is raised. The action of this machine is as follows:—

Supposing the machine to be used for either mortising, grooving, or slotting, a tool adapted to the peculiar kind of work is inserted in the socket in the end of the shaft; the wood or other material to be operated upon is then placed between the jaws, H H′, and its position beneath the cutting-tool determined by means of the hand-wheels, C and G. The cutter is then set to work by depressing the lever, R, which brings the cutter into contact with the wood. The lever, R, is then raised, which causes the rod, *p*, to be depressed, and (through the medium of the stop, *r*, bell-crank leve r, Z, and pall, Y) the spur-wheel, X, to make a partial revolution, while the pinion, E, gearing into the rack upon the underside of the slide, B, causes that slide to be moved forward the requisite amount of feed so as to advance the food for a fresh cut. The amount of feed can be regulated by shifting the stop, *r*, either up or down the rod, *p*. When it is desired to reverse the cutter, the pin, *f*, is withdrawn, the shaft turned, and the pin again inserted in the opposite hole, at the same time the pall is reversed, so as to act upon the opposite side of the spur-wheel, whereby the slide, B, is caused to traverse in the opposite direction.

When it is desired to apply the machine to drilling or boring, it will be necessary to employ a tool adapted for such purposes, and to give to the spindle or shaft carrying such tool a rotary motion by means of the bevil-wheels, S and T, and crank-handle, W.

CALORIC ENGINES.

ACCOUNT OF THE PRINCIPAL SYSTEMS PROPOSED UP TO THE PRESENT TIME.

It would be very difficult, if not impossible, to determine with any certainty who was the discoverer that first entertained the idea of constructing caloric engines.

According to the *Scientific American*, air must have been employed in France, as a motive power, anterior to steam. This is a somewhat vague statement; but a positive fact, invested with deep interest in the present day, when the fame of Ericsson and his caloric engine has become so widely diffused, is recorded in the journal to which we have just referred.

Dr. Robert Stirling, parish minister of Galston, in Scotland, took, in 1827, a patent for an engine worked by hot air. This machine is represented and briefly described in the *History of Steam-Engines*, by Galloway and Hebert, published at London in 1832—that is to say, the year before that in which Col. Ericsson took his first patent. The principle applied in the Ericsson engine, as in almost all the caloric engines constructed or proposed in these days by different inventors, and which consists in depriving to a great extent of its caloric, the air which escapes from the cylinder, in which it has produced the required effect, to deliver this caloric to a new supply of air succeeding to the first and entering the cylinder—and in passing this air through canals or reservoirs filled with metal slips, plates, tubes, &c., so as to bring it into contact with an extensive metallic surface; in a word, the principle of the *regenerator* belongs to Dr. Stirling.

Fig. 1 represents Stirling's hot-air generator. This generator consists of a cylinder, A, with a spherical bottom, B, and in which moves a displacer, or kind of piston, C.

This peculiarity of the spherical bottom, which is reproduced in Ericsson's engines, is intended to bring a large metallic surface in contact with the air to be heated, the spherical bottom being placed immediately over the furnace, and heated directly by the flame or gases from the fuel.

The displacer, C, is composed of a packing of metal plates laid on one another, and pierced with zig-zag holes, pretty large, to allow a passage to the air, but so arranged among each other that the air, to pass from the one to the other, is forced to circulate between the metal plates. The lower part of this displacer ought to be fitted with a case or chamber, filled with fragments of brick, or some non-conducting substance. The displacing piston, which, as we have seen, performs at the same time the part of a generator, is connected with the machinery by the rod, *d*.

This generator is brought into communication by a tube with the lower part of an ordinary steam-engine cylinder, which is not represented in the figure, whilst another generator, quite similar, communicates with the upper part of the same cylinder.

Let us suppose the displacer at the bottom of its course: all the air in the regenerator will then be above the piston, kept by the latter from contact with the surface of the spherical heater, and cooled, moreover, by a current of water circulating in the chamber, *a*, of the double cover of the cylinder.

If the displacer rises, the air will naturally be forced from the space above to that below the displacer, and, to do so, must flow through the holes of the metal plates. This air will then be in contact with the heated surface, separated by the displacer from the cold part of the regenerator—it will therefore expand by the effect of the heat imparted to it; and being, as we have stated, in communication with the lower part of a cylinder, the effect of this dilatation will be to raise the piston of the latter.

Every time that the air passes from under the displacing piston of the regenerator to the space above it, through the metal plates of which it consists, it gives up to them most of its caloric, which it recovers from them in its passage back. This system effects a considerable economy of fuel.

The two generators acting simultaneously in a reciprocal manner—that is to say, the one rising while the other falls, and *vice versa*—it is obvious that the piston of the cylinder with which they communicate, being impelled by the dilatation of the air alternately above and below it, while the air opposed to that which is diluted is at the same time contracted, will rise and sink alternately, exactly like that of a steam-engine.

The second generator is not indispensable; the atmospheric pressure would suffice to move the piston from behind when the air of the generator contracts.

Mr. Stirling, in concert with his brother, Mr. J. Stirling, engineer, Dundee, took several patents for improvements in his hot-air engine. Mr. J. Stirling, in 1846, read a report on this engine at a meeting of the Institute of Civil Engineers. This report was published in Vol. XLV. of the *London Mechanic's Magazine*. Mr. Stirling there stated, that in his first patent, of date 1827, he had specified that the regenerator might be composed indifferently of plates pierced with holes or of *wire-gauze*.

The use of wire-gauze has since been proposed for the same purpose by M. Franchot, of Paris, in 1838, as proved by a memoir presented by that engineer to the Academy of Sciences, on the 10th August, 1840. Lastly, in 1850, Ericsson, in a patent which he took in England, adopted also the use of this gauze.

Ericsson's first patent dates from 1833, and was taken by that inventor in England.

Fig. 2 represents, in vertical and longitudinal section, the engine described in this patent.

A is the regenerator, which, in this engine, consists of a reservoir or cylindrical vessel closed at both ends by the plates, B. These plates are traversed by a great number of thin tubes, C, which extend from the one plate to the other, through the

body of the regenerator, and open into the chambers, D and E, at each of its extremities. By means of these chambers, the tubes, *c*, freely communicate with each other, without communicating, however, with the interior body of the regenerator, A.

A certain number of metallic partitions, *d*, divide the interior of the regenerator into several compartments, which communicate with each other by openings, *d'*, made in each partition alternately above and below.

The tubes, *c*, are also furnished internally with division plates, formed like portions of discs, and arranged alternately on opposite sides in the tubes, as shown in the detail figures 3 and 4.

F is the driving cylinder of the engine, called by Ericsson the *hot cylinder*. At the other end of the machine is a cylinder of smaller diameter, G, called the *cold cylinder*, and which plays the part of a feed-pump, by continually sending back to the regenerator, and thence into the furnace and the hot cylinder, the air which it receives from the latter after it has served its purpose.

The pistons, *f* and *g*, of these two cylinders are connected with each other by the beams, H, (one on each side of the cylinders,) by means of connecting-rods and cross pieces attached to the extremity of the piston-rod, and to which the connecting-rods are joined, as in many steam-engines. For the rest, the cylinders are each furnished with slide-valves, *h*, which differ little from the common construction, and are governed by cams riveted on the main shaft, I.

J is a tube, forming part of a series of similar tubes arranged alongside one another in a furnace, K, in which they are continually exposed to the action of a fire, L, the combustion of which is kept up by an ordinary current. The hot gases developed by this combustion circulate through the chamber, M, which contains the regenerator, and thence escape by a chimney.

The tubes, J, of the furnace, all terminate at one of their extremities in the chamber, D, and at the other in a flue, N, which opens into the distributing chest, O, of the hot-air cylinder.

P is a refrigerating apparatus, which serves, as we shall see, to deprive the air of the heat which the regenerator has not been able to take away entirely, and which consists of one or more tubes exposed to the action of some refrigerating fluid, these tubes being, like those which traverse the regenerator, divided internally by small metal discs.

The better to understand how the machine operates, let us take it at a certain point of its progress.

The valves are in the position represented in fig. 2. A free communication is established between the upper part of the cylinder, F, the distributing chamber, O, the flue, N, the tubes, J, the chamber, D, the interior of the tubes, *c*, the chamber, E, the tube, Q, the distributing chest, R, and the upper part of the cold cylinder, G.

The air contained in the tubes, J, expands, and the pressure produced by this expansion acts at the same time on the piston, *f*, and the piston, *g*, tending to make them both descend. The pressure per square inch being the same on each of the two pistons, the difference of the total pressure on the two, resulting from the difference of their surfaces, will make the piston, *f*, descend, and this will raise the piston, *g*, the consequent dilatation of the air in the tubes, J, being added to that of the air which has already entered the cylinder, F, and has not yet cooled down.

During this movement, the air from the preceding stroke of the piston, which is contained in the lower part of the cylinder, F, is pressed down and escapes by the tube, *n*, into the body of the regenerator, A, on the outside of the tubes, *c*, to which it gives up the greater part of its heat, circulating from one compartment to another by the openings, *d'*. Thence it passes through the tube, P, where it is thoroughly cooled, and enters the lower part of the cold cylinder, G. As, in cooling, this air diminishes in volume, the whole quantity of air proceeding from the hot cylinder finds room in the cold cylinder, without producing any inconvenient resistance.

When once the piston, *f*, has arrived at the bottom of its course, and the piston, *g*, at the top, the position of the valves changes, and the two pistons commence, by the operation of the same causes, to proceed in the opposite direction, as may be easily explained.

The air then contained in the cold cylinder is sent back in its turn to the hot cylinder, passing through the tubes, *c*, of the regenerator, which give it back the caloric it had yielded to them in its passage in the opposite direction, increased by an additional quantity of heat received in its passage through the tubes, J.

The same air, therefore, is always used over again, alternately giving out and receiving back its caloric.

It is evident, from this arrangement, that since the effective power is equal to the difference of pressure on the two pistons, it must be an object to increase this difference by diminishing the area of the cold piston, in proportion to that of the hot piston. At the same time the cold air contained in the small cylinder must fill exactly, when expanded, the hot cylinder.

A temperature of about 570° Fahr. is required to double the volume of atmospheric air; and, as a higher temperature would soon injure the machinery, the proportion of 1 to 2 is the greatest that can be adopted for the relative volumes of the cylinders, and consequently for that of the piston surfaces.

In the engine represented in fig. 2, this proportion is only as 2 to 3.

Messrs. Rivière and Braithwaite imported into France, in 1834, a caloric engine, which is simply the one we have described, slightly modified. This machine is composed of three equal cylinders, two hot and one cold, which is equivalent to two cylinders in the proportion of 2 to 1.

As the loss of heat by radiation is the same whatever be the density of the air, and further, as the total pressure exerted on the two pistons, and therefore their difference, increase with the tension of the air in the apparatus, it is advantageous to inject and condense beforehand, by means of a pump, a certain quantity of air in the interior of the machine.

M. Franchot proposed, on his own account, in 1836, a caloric engine, which presented some analogy with that of Ericsson; only, in place of using continually the same air, the machine allowed the air employed in the driving cylinder to escape, after depriving it of its caloric, and the cold cylinder really performed the part of a feed-pump.

The air employed in the driving cylinder escaped under the grate of the furnace, and served to excite the fire and to supply it with oxygen; from thence, raised to a high temperature, this air passed, conjointly with the gaseous products of combustion, into the tubes of the generator, similar to those indicated by *c*, in fig. 2, but opening into the atmosphere. The air, in passing through the tubes, gave up to them its caloric.

The cold cylinder receiving, by its valves, the external atmospheric air, compressed this air into the body of the regenerator, where it took up the heat given out by the warm air in escaping, and was finally delivered over the furnace, where it received additional heat, and thence arrived at the driving cylinder.

The dilatation acquired by this air enabled it to maintain, in the driving cylinder, the pressure required for working the engine. But since, if this pressure remained constant to the end of the course of the piston, there would be a loss of dynamic power, inasmuch as the interior air would then have been suddenly restored to the atmospheric pressure, the valve intercepted the admission of the hot air into the driving cylinder, at $\frac{3}{4}$ths of the course of the piston, so as to allow the air in the cylinder to be completely deprived of its tension, before opening the communication with the other extremity of the same cylinder. During this time the cold-air pump continuing to operate, the air which it injected would be compressed into the body of the regenerator.

Supposing the large cylinder to be double the size of the cold-air pump, and that the air in its passage from the one to the other doubled its volume by about 570° of heat, it is evident that, if the valve did not shut till the driving piston arrived at the end of its course, the interior pressure would be nothing.

But the valve shutting at $\frac{3}{4}$ths of the course of the piston, the pressure would become equal to 1 divided by $\frac{3}{4}$, or $1\frac{1}{3}$ of that

of the atmosphere. The effective power is, therefore, the expansive force of the air, passing from the pressure of ⅓d of the atmosphere to that of 1 atmosphere, and the loss of effective power is nothing, since the air is entirely deprived of its expansive force.

On the 10th August, 1840, M. Franchot presented to the Academy of Sciences, a memoir on the subject of another system of caloric engines, which he had patented in 1838. Fig. 5 is taken from the drawing which accompanied that memoir, and gives a very clear idea of the system proposed by M. Franchot. It represents, in vertical section, the apparatus with which this inventor made his first experiments.

a, *a′*, are two generators, or cylindrical cases of plate-iron, the upper parts of which enter a furnace, *m*, maintained at the temperature of about 600° Fahr. by a fire, F, while the lower parts dip into the refrigerating vessels, R, R′, filled with cold water kept at the temperature of 60° to 80° Fahr., for the purpose of cooling them.

b, *b′*, are air compressers, or displacers, which, both on their outside and inside, leave a passage for the air, that it may pass from one end of the generator to the other. These displacers are worked by the engine, by means of the rods, *t*, *t′*.

The generators, *a*, *a′*, are connected together by a cylinder or pump, *n*, *n′*, and bent tubes, L, L′. In the pump, *n*, *n′*, moves the piston, P, the prime mover of the engine; the cylinder, *n*, *n′*, is full of water, and it is by the intervention of this water that the pressure of the hot air is transmitted to the piston, P.

The bodies of air are displaced simultaneously, but reciprocally, by the displacers; that is to say, the one is heated while the other is cooled, so that the difference of pressure thence arising in each of the generators, acts immediately on the liquid surface, and, consequently, on the piston, which is moved along till the balance of pressure is re-established.

Thus, suppose that, in our fig. 5, the displacer, *b*, rises while *b′* descends. The body of air in the generator, *a′*, passing from below upward, will arrive at the part contained within the furnace, and will acquire a degree of heat sufficient to double its volume. It will then tend to expand, and since the communication from the top to the bottom of the generator is always open, this mass of air will press on the part of the liquid contained in the pump-body or cylinder. On the other hand, the hot air of the generator, *a*, will pass from above downward, and will be cooled from 600° to 70°, both by the water in the vessel, R, and that in the pump-body, *n*, *n′*, from which a sieve, *r*, *r′*, attached to the lower part of each displacer, raises in its upward movement a certain quantity, which falls back in a shower, and cools the air, making it contract into half the volume which it occupied in the furnace.

These two effects combined, the dilatation on the one hand, and the contraction on the other, will evidently work the piston in the direction from *n* to *n′*. When the piston reaches the end of its course, the respective position of the displacers changes, and an opposite movement is produced.

Figs. 7 and 8 represent, in vertical and horizontal sections, a caloric engine, for which M. Franchot obtained a patent on the 31st May, 1845. To develop the principle, we shall have recourse to fig. 6, which the inventor employed to explain his system, this arrangement being its simplest form.

a b c is a cylindrical case, of which one extremity, *a*, is heated, and the other extremity, *b c*, cold. R is a full cylinder, or displacer, which receives an alternating movement by the rod, *t*.

When this displacer descends, the air flows from the cold chamber, F, to the hot chamber, C, by the pipe, D, which keeps these two chambers in constant communication.

By this change of place, the air is heated, and by its dilatation repels the driving piston, P, which works in the part, *b c*, of the cylinder, *a b c*.

If the displacer rises, the air flows from the hot chamber, C, to the cold chamber, F, cools down in its passage, and, by the contraction which it undergoes, permits the driving piston to return to its former position.

It will be seen that this arrangement is merely an advantageous simplification of the system which we have described above, with the aid of fig. 5.

That the expansion of the air may be effected under the best conditions, it ought to take place in the hot chamber, without its mass being separated into two portions of unequal temperatures, C, F.

Now, as it is important to preserve the piston, P, from the action of a temperature so high as to put it out of order, it has been proposed to place it partly outside the generator, partly in the cold part of that cylinder, covering it, during its recoil, with the displacer, R, which would serve to screen it, and become, in some sort, a prolongation of the piston itself.

This arrangement—excellent in a theoretical point of view—would seem, at first sight, exceedingly simple, but it is attended with many inconveniences which the inventor has attempted to obviate by introducing certain improvements.

The following is the engine which formed the subject of the patent of 1845, already mentioned.

Fig. 7 is a vertical section along the axis of the generator, and fig. 8 a horizontal section following the line 1—2.

The generator is composed of three distinct cylinders, placed the one over the other; A, a cold cylinder, in which works the piston or displacer, B; C, an intermediate cylinder, heated directly by the fire, D; and E, a third superior cylinder, in which moves the driving piston, F.

To preserve this piston, F, from being injured by the heat, it may be surrounded with a water-box, *a*, which will limit its temperature to 212° Fahr. The piston is likewise protected, at its lower part, by a drum, *b*, filled with bodies that are bad conductors of heat.

To join these cylinders, thus placed one over another, without allowing sensible exchanges of temperature between them, an isolating joint, *c*, is used, which simply consists of a very thin iron ring, fitted into grooves on the rims of the cylinders. This ring, by reason of its thinness, forms a joining little favourable to exchanges of temperature between the cylinders which it connects.

The displacer consists of two parts: the lower part, *d*, is cold, and has a double bottom. In this double bottom circulates a current of cold water through the hollow rods, *e f*. The upper part, *g*, of the displacer is hot, and serves for a screen. It enters the hot chamber, C, placed immediately above. These two parts are united by isolating joints, and are filled with bad conductors.

The circulation between the hot and cold chambers is effected by a concentric pipe, G, on which the displacer, B, exactly fits, and which serves for a guide to it. The air passes from the cold chamber, A, by copper tubes, *h*, surrounded with water, into the pipe, G, filled with rolls of metal plates, so as to leave a sufficient passage for the air, and thence it arrives at the chamber in which works the driving piston, F.

The hot intermediate cylinder consists of three distinct parts: the upper chamber, *i*, into which descends the case of the driving piston; the lower hot chamber, *j*, into which penetrates the case of the displacer, *g*; and lastly, the intermediate chamber, *k*, in which the heating of the two chambers, *i* and *j*, is performed.

Fig. 8 is a section of this chamber, *k*. The flame of a furnace, D, circulates by the channels, 1, 2, 3, of this chamber, and afterwards passes round it by the space, 4, before escaping by the chimney, *l*. There is no communication between these channels and the two hot chambers, but these two chambers communicate with each other by holes which pass in a vertical direction through the partitions, *m*.

When the displacer descends, the air emerging from the cold chamber, A, passes, as we have stated, by the tubes, *h*, then by the pipe, G, in which it acquires a degree of heat by contact with the metallic plates, the heat of which goes on increasing from below upward. The air arrives in the chamber, *i*, penetrates into the chamber, *j*, by the holes in the partitions, *m*, where it is thoroughly heated, and fills the space left void by the displacement of the piston. This air, heated to a temperature of about 570° Fahr. above its original temperature, expands till it occupies double its former volume, and thereby raises the piston, F.

When, on the contrary, the displacer rises, the air expelled from the chamber, *j*, passes back by the holes, *m*, and by the pipe, G, where it restores to the sheets of metal the heat it had

received from them; it reaches the tubes, *h*, in which it is completely cooled down, and re-enters the cold chamber, A. This air contracting produces a diminution of pressure, and the piston, F, again descends to re-establish the equilibrium.

It is important that the displacing of the air be effected in great measure before its change of volume, and reciprocally, that the change of volume take place without displacement of air; in other words, it is necessary that the displacer change its position during the dead rest of the piston, which gives it only a quarter revolution of the crank to accomplish its course; during a second quarter, it will remain stationary; during a third quarter, it will move in the opposite direction; and lastly, during the fourth quarter, it will be again stationary.

The production of this movement was effected in a very ingenious manner by M. Franchot. We shall not undertake to describe the different means employed for transmitting the movements of this engine; it is quite enough to have pointed out the principle on which the movement is produced, by means of the alternate contraction and expansion of the air.

This machine may be composed of a single generator, similar to that we have described, or of two of these generators yoked together, and acting alternately.

M. Franchot improved on different occasions his hot-air engine. We shall refer to one of these improvements, described in his fourth patent addition of 1841, which consists of a machine with a single and horizontal generator.

This generator is simply that represented in fig. 6, constructed and applied in the simplest manner in practice, and laid horizontally. Its hot part has a conical form, the same as the corresponding part of the displacer.

The displacer, which is fitted as exactly as possible in the generator, serves for an air reservoir, and communicates by means of a flexible tube, which traverses the piston, with the opposite surface—that is to say, in front of the latter—maintaining thus a mean pressure nearly constant, by reason of the great internal capacity of the displacer. This pressure performs the part of a spring, and the gaseous medium, according as it is heated or cooled, produces a pressure greater or less than that of the air in the reservoir; hence arises a motive force, which produces the come-and-go movement of the piston.

The flue, D, filled with pieces of metal or wire-gauze, becomes the regenerator. Moreover, cold water being injected between the piston and the displacer, when these arrive at the end of their course furthest removed from one another, the water serves to thoroughly cool the air which has just passed from the hot to the cold part of the apparatus through the regenerator.

The form of this machine and its simplicity render its application very convenient. It was constructed in 1841 and 1842, by M. Philippe, engine-maker, at Paris, in concert with the late Mr. Codner, a young English engineer; the results which it gave were very satisfactory—a power of four horses with less than 9 lbs. of coke per hour.

This engine was abandoned in consequence of an accident happening to the displacer during the removal of the apparatus. This piece, which was made too thin, broke, and different circumstances prevented the inventor, to his great regret, from refitting the apparatus.

Figs. 9 and 10 represent the latest engines of Ericsson, which he patented in England in 1850, and in America in 1851.

Fig. 10 is a drawing of the engine in the *caloric ship*, to which Ericsson has given his own name.

In each of these engines, the inventor has combined the driving piston with the cold piston, making them work simultaneously in two cylinders, placed one over the other, and of unequal diameters, so that the pistons are single-acting; it is necessary also to provide two pairs of pistons, coupled together, and working the same beam.

Let us give our attention in the first place to fig. 9.

A and B are two cylinders, placed the one over the other, of unequal diameters, and nearly of the same depth. B is the hot, and A the cold cylinder, or supply-pump; *a* and *b* are the respective pistons of these two cylinders; they are connected by four rods, D, so as to constitute one body, moving together. From the piston, *a*, rises the rod, *a'*, which transmits to any machinery the movement obtained.

The cylinder, C, is simply a prolongation of B; and in this is inserted the part, S, which acts as a screen to the piston, *b*, in the lower part of its course. This chamber is fitted with a spherical bottom, under which is a furnace, R. H is also a cylindrical vessel with a spherical bottom, and here is effected the heating of the air by means of a furnace, R'.

The screen, S, of the piston, *b*, is a cylindrical vessel with a spherical bottom, corresponding to the shape of the bottom of the chamber, C. This cylinder is attached to the piston, and is filled with bad conductors of heat, such as ashes, charcoal, &c., to protect the piston from the direct action of the heat, and the injury which would result therefrom.

In the cold cylinder, E is a valve opening inward, and F another opening outside the cylinder in a valve-box, *c*, which communicates by a tube with the cylindrical reservoir, G.

L and M are the regenerators, consisting of two cubical vessels, filled in their whole capacity, except for a small space at the top and bottom, with pieces of wire-gauze arranged above one another. The spaces left empty above and below are intended to make the air diffuse itself over the whole surface of these sheets of wire-gauze, to penetrate equally through them.

The reservoir communicates with the hot-air chamber, H, by two tubes, *f* and *g*, which are alternately opened by means of the slide-valve, N.

J and K are two conical valves worked by the engine, by means of the rods, *j* and *k*, exactly fitted to each other.

The chambers, H and C, are heated by the fires, R', R, the hot gases from which escape by the pipes, *l* and *l'*, which serve as the chimney, and envelop the reservoir, G. Q is a pipe and stopcock fitted to the reservoir, G, and by which the air is compressed in that reservoir, so as to produce a pressure of 4 to 5 lbs. per square inch.

The communication between the reservoir, G, and the chamber, H, is kept up at this stage by the tube, *f*, and the valve J is opened, while K is shut.

The air, expanding, exerts a pressure which, on account of the difference of surface of the pistons, will cause the piston, *b*, to ascend, and consequently, *a*, likewise, which will expel through the valve, F, the whole of the air contained in that cylinder; and this air, driven through the reservoir, G, and the tube, *f*, will traverse the hot regenerator, L, acquiring therein a certain degree of heat, to which will be added that produced by the furnace, R'. When the pistons arrive at the top of their course, the valve J shuts, and K opens. The pistons, which are single-acting, impelled partly by their weight, partly by the fly-wheel, and more especially by the action of the other apparatus—these pistons, *b* and *a*, will then descend. The air contained in the cylinder, B C, will be pressed out through the valve, K, the box, *e*, the tube, *h*, the opening, P, and the tube, *g*, through the cold regenerator, M, to which it gives up its heat. Thence it passes by the opening, O, the tube, *g*, and tube, *i*, and arrives by the valve, E, into the cylinder, A, in which the piston makes room for it as it descends.

The pistons having reached the bottom of their course, the valve K shuts, while J opens, and the pistons rise again as before.

It is obvious that the temperature of the wire-gauze in the two regenerators will be reversed after a certain number of strokes of the piston; for that in the regenerator, M, through which the hot air passes, will go on gradually increasing, while that in the regenerator, L, which is traversed by the cold air, will in like manner go on diminishing; so that a period must arrive when the refrigerating power of M, and the heating power of L, will be nothing. At this point, which can be exactly ascertained, and which, according to the size of the regenerators, will more or less nearly correspond to the fiftieth stroke of the piston, the valves, N, are reversed, so that the hot air from the cylinder, C, passes through the cold regenerator, L, while the cold air from the cylinder, A, traverses the heated regenerator, M.

The engine represented in fig. 10 has, as will be seen, only one generator, traversed alternately by the air which enters the driving cylinder, and by that which proceeds from it. Moreover, this engine, instead of employing always the same air, allows the whole of the air employed to escape into the atmosphere, while the cold cylinder constantly feeds it with external air.

A, A, are the supply cylinders, and B, B′, the driving cylinders; the cold and hot pistons are a, a', and b, b', respectively. The hot pistons are furnished with screens, S, like those of the engine already described; and they are connected by rods or supports, D, with the cold pistons.

The hot cylinders are furnished with prolongations, C, C′, having spherical bottoms exposed to the action of the fires, R, R′. These spherical bottoms were constructed of sheet-iron, but the action of the fire having been found to destroy them in a short time, the inventor has resolved to replace them with bottoms of cast-iron.

The cold pistons are provided with valves, E, E′, and the corresponding top plates of the cylinders are also fitted with valves, F, F′, which open into a chamber, G, communicating by the tubes, H, H′, with the space below the hot pistons. This communication is not direct; it is effected through the intervention of double valve-boxes (of which only that on the right hand, I, is shown in the figure), and of the regenerators, J, J′.

Under the valve-boxes are fitted tubes, K, opening into the atmosphere.

The cold pistons work a beam, L, to which they are joined by connecting-rods, l, l'. This beam carries two rods, m and n, connected by pins at their extremity; and at the point of their junction a crank, M, is attached, which works by the lever, N, on the shaft, O.

The valves, x, y, are worked by the engine, x serving to establish the communication between the hot and the cold cylinder, and the other, y, between the hot cylinder and the atmosphere.

Suppose the pistons, a, b, to have just recovered from their lowest point, and begun to ascend, while, consequently, the pistons, a', b', begin to resume their downward course. The valve, x, is then opened, and y shut; while the valves of the corresponding box of the other cylinder (not shown) are, contrariwise, shut and opened.

There is, therefore, on the one hand, a communication established between the cylinder, B C, the regenerator, J, the box, I, the tube, H, and the upper chamber, G; on the other hand, communication is opened between the cylinder, B′ C′, the regenerator, J′, the box, I′, and the external atmosphere.

A constant mean pressure is maintained in the chamber, G, and the tube, H, and has been previously produced by compressing into these spaces, by means of a pump, air with a pressure of 1·6 atmospheres. This pressure makes the pistons ascend, till the air contained in the cold cylinder has reached the same degree of tension. Then, the expansion of the air by the heat continuing to raise the pistons, the valves, F, open, and the tension of the air acting with a force equal to the difference of the total pressures exerted on the surfaces of the pistons, which are in the ratio of 3 to 2, the pistons continue to rise to the end of their course, making the whole of the air contained in the cold cylinder to pass into the chamber, G.

To turn to account the expansion of the hot air, and to maintain the mean pressure constant in the chamber, G, the valve, x, is shut at about two-thirds of the course of the pistons.

As soon as the pistons have arrived at the top of their course, the valve, y, opens, and the air contained in the hot cylinder is free to escape into the atmosphere. The valve, y', of the other cylinder, shuts, x' opens, and the pistons, a', b', begin to mount, causing the descent of the pistons, a, b. In this movement, the air of the hot cylinder, B C, is driven into the atmosphere, giving up its heat to the wire-gauze of the regenerator; the valves, E, open, those marked F close, and the cylinder, A, fills with a fresh quantity of cold air.

It will be seen, therefore, that the pistons work alternately, being single-acting. In their downward course they have no effect.

Ericsson employs, in his *caloric vessel*, two engines like those we have just described; the other engine works the crank, N, by means of a connecting-rod, M′, at right angles to M.

The diameter of the driving pistons is 14 feet, which corresponds to a surface of 153·8 square feet. The cold piston has a diameter of 11·3 feet, with a surface of 100 square feet. The ratio is, therefore, as we have stated, about 3 to 2.

The range of the pistons is 6 feet.

During the last trial, which took place in rough weather, the mean result obtained was 6·5 turns of the wheel per minute.

It is stated that less than five tons of coal were consumed in the twenty-four hours, during a trial which lasted seventy-two hours.

The effective power being, by the calculations of several competent persons, from the best data that could be got, about 225 horses, the consumption, per horse power per hour, would be a little more than 2 lbs.

This economization of fuel would, therefore, indicate a great advantage in favour of hot air over steam as a moving power; but, as we have already stated, the enormous proportions of Ericsson's engines, and of the volumes generated by their pistons (1,720 cubic feet for each stroke of the piston, with one engine of four pairs), has hitherto rendered them very disadvantageous in use, and, in many cases, impracticable.

Among those who have devoted their time and attention to caloric engines, we may further mention M. Andraud, who has made numerous experiments on the application of this motive power, and who, in 1844, ran on the Versailles Railway an air locomotive, in the presence of a commission appointed by Government. The locomotive worked by the action of air, which was first compressed in a boiler, and then expanded by heat. The mode of expansion employed by him had some analogy with that which is now applied in the ship *Ericsson*, only it worked at high pressure, and, instead of folds of wire-gauze, the generator consisted of a worm sunk in a peculiar kind of furnace; the air, in passing through this convoluted tube, expanded to a certain degree, and then, on arriving in the driving cylinders, it underwent a new dilatation, the spherical bottoms of these cylinders being fitted with blocks of cast-iron raised to a white heat.

We may mention also the system of M. Froelich, patented in 1847, and differing sensibly in principle from that of the machines we have described.

The principle applied by M. Froelich was this:—"The specific gravity of air diminishes when its temperature is raised, and it tends to rise with a force equal to the difference between its own weight and that of the volume of cold air of which it occupies the place."

The inventor proposed to place over a furnace an inverted bell-shaped vessel, communicating, at its upper part, by means of a chimney or flue, with the distributing box of an ordinary steam cylinder. The ascensional force of the air, greater in proportion to the increase of its temperature, and acting alternately on each side of the piston—the opposite surface being, at the same time, subjected to the atmospheric pressure—would give a corresponding reciprocal movement to the piston.

The subject of caloric engines engages the active attention of a great many individuals. Several plans have lately been submitted to the French Government, which recognises the importance of substituting heated air for steam, and encourages the efforts of engineers who exercise their skill and ingenuity in endeavouring to solve the problem.

A new system, just proposed by M. Franchot, and very simple in its machinery, since it requires neither valves, nor displacers, nor feed-pump, appears to present decided advantages over all the systems hitherto devised, either by himself or other engineers. We shall give a description of this on a future occasion.

THE SCIENCE OF PHRENOLOGY.

CHAPTER VIII.

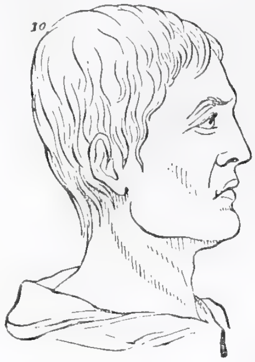
ORDER I.—FEELINGS.

Genus II.—Sentiments.

We now proceed to consider those developments of the brain, which phrenologists have denominated Sentiments. Some of these sentiments are equally manifested in man and the inferior

animals, others are proper to man alone. The first to which we shall direct our attention is—

10. Self-Esteem.—This feeling is generally considered as factitious, or as the result of social circumstances; but Phrenology proves that it is fundamental. A vast opinion of their own persons is sometimes observed in individuals, who have no claims to influence over others or to particular notice, either by birth, fortune, or personal talents. Pride is a sentiment that is commonly more active in men than in women. By the influence of its organ, the insane fancy themselves great geniuses, kings, emperors, ministers of state, and several even the Supreme Being. The horse, peacock, turkey-cock, &c., manifest feelings analogous to pride. Its great activity in society gives arrogance, self-conceit, pride, haughtiness, and an authoritative behaviour. Combined with superior sentiments and intellect, it contributes to true dignity and greatness of mind: its deficiency disposes to humility.



Dr. Gall thus relates the history of its discovery:—"A beggar attracted my attention by his extraordinary manners. I reflected on the causes which, independently of an absolutely vicious conformation, or of misfortunes, could reduce a man to mendicity, and believed I had found one of the chief of them in levity and want of forethought. The form of the head of the beggar in question confirmed me in my opinion. He was young, and of an agreeable exterior, and his head in the region of circumspection was very narrow. I moulded his head, and on examining it with attention, remarked, on the upper and back part of the middle line, a prominence extending from above downwards, which could arise only from the development of the brain beneath. I had not previously observed this prominence in other heads, and for this reason I was very anxious to discover what it indicated. His head was small, and announced neither strong feelings nor much intellect. After many questions addressed to the beggar, with a view to discover the remarkable traits of his character, I requested him to relate his history. He said he was the son of a rich merchant, from whom he had inherited a considerable fortune: that he had always been too proud to condescend to labour, either for the preservation of his fortune, or the acquirement of a new one, and that this unhappy pride was the sole cause of his misery. This reminded me of persons who never cut their nails, in order to convey the idea that they are not obliged to work. I made several remarks to him, and let him know that I doubted his veracity. But he always reverted to his pride, and assured me that even now he could not resolve to follow any kind of labour. Although it was difficult to conceive how pride should cause a man to prefer begging to working, yet I was led, by this person's assurances, to reflect upon the sentiment of pride."* The organ is now, by indisputable facts, established.

Pride, arrogance, superciliousness, self-sufficiency, &c., are all derived from the same source, namely, Self-Esteem, inordinately developed, or not sufficiently controlled by the superior sentiments and intellect. We will examine it under a few of its aspects.

There are few men, says Addison, who are not ambitious of distinguishing themselves in the nation or country where they live, and of growing considerable among those with whom they converse. There is a kind of grandeur and respect which the meanest and most insignificant part of mankind endeavour to procure in the little circle of their friends and acquaintance. The poorest mechanic, the man who lives upon common alms, gets him his set of admirers, and delights in that superiority which he enjoys over those who are in some respects beneath him. This ambition, which is natural to the soul of man, might receive a very happy turn, if it were rightly directed, and contribute as much to a person's advantage, as it generally does to his disquiet and uneasiness.

* Gall's Works, vol. iv., p. 156.

Among the various motives to action by which mankind are governed, there is none which exercises a wider influence than the love of power. This is little attended to among ordinary individuals, because cases do not occur for its exercise in a very extended form, and the innumerable instances in which it displays itself in little matters, escape observation from the very circumstance of their frequency. Yet almost every family will furnish us with instances of persons who are desirous to domineer over those around them; and that the principle is deeply rooted in human nature in its present state, is evinced by its spontaneous development in the minds of the young. One cannot become domesticated in a seminary for youth, without seeing it strongly displayed. Even the greatest care on the part of the master, can seldom prevent the exercise of cruel tyranny on the part of the stronger children over the weaker. But when we turn our view from private scenes to public, the monster stalks before us in the most gigantic form. How many conquerors, miscalled heroes, figure in the pages of history, who have spent their lives in the endeavour to aggrandize their power by the subjugation of surrounding nations? And how many sovereigns, whom the vicinity of more powerful states has prevented from signalizing themselves by foreign conquests, have gratified their lust of dominion, by striving to render their authority in their own kingdoms more absolute, setting their own will above the laws, and disposing at pleasure of the lives and property of their subjects? In short, the lust of dominion in private and in public, with the cruelty and oppression with which it is associated, is the source of the greatest evils that afflict mankind. Even the lust of gold, the *auri sacra fames*, so celebrated for the mischiefs of which it is the origin, is, in comparison, a gentle demon. The lust of dominion, soften it as we may by the milder names of ambition and love of power, is the most direful evil in the human character.*

But Self-Esteem, when properly guided and controlled by Conscientiousness, excites feelings of self-respect, productive of the most excellent effects, and at the same time manifests an instinctive horror of whatever is low or degrading. Conscientiousness seems to employ this faculty as a strict and vigilant guardian, to watch over the lower feelings of the mind. For instance, when any of the propensities seek an improper gratification, or show a tendency to go beyond the legitimate exercise of their proper functions, Self-Esteem raises an admonitory check—reasons, so to speak, with the impulsive propensity that seeks to indulge itself at the expense of justice and virtue, and shows the probability of loss of character and reputation. It is the means of imparting and sustaining that decent pride, so indispensable to the upright discharge of the duties of life.

Self-Esteem, when guided by Conscientiousness, and associated with Firmness, will never be dishonest; it will curb all the excessive cravings of Acquisitiveness—for though it may love both power and wealth, it will never descend to meanness to acquire either. Self-Esteem, associated as before observed, will not be likely to indulge in slander and lying; and it thus operates as a check upon Secretiveness, preventing it from any excessive or undue exercise of its functions. Thus Self-Esteem is calculated to restrain Destructiveness, curb the irrascibility and litigious feeling of Combativeness, prevent cunning in Secretiveness; and lastly, Self-Esteem lends to Benevolence, nobleness and generosity; gives endurance to the moral and civil virtues, and behaves itself wisely and discreetly.

As the guardian of the inferior propensities, its locality is remarkable; being situated at the posterior part of the vertex of the head, it seems to superintend those organs beneath it, itself being in turn superintended by Conscientiousness and Firmness just above it.

When possessed in an inordinate degree, and if the education has been neglected, or none of the higher sentiments are sufficiently powerful to moderate its action, the abuses it indulges in are dangerous indeed. Educators have here a

* Rev. S. Noble, Plenary Inspiration of Scripture.

proper field for usefulness, and the utmost discrimination will be necessary to keep this feeling in abeyance. Those children in whom the organ is moderately developed, are generally tractable and obedient; in others, where it is large, it produces arrogance, and an untameableness of temper which cannot be too deeply deplored. Teachers should beware of emulation to such children as these, for emulation to such minds will be sure to increase the power of the organ, and thus the education of the young prepares for a career of rivalry and ambition. For our own part, as an educational adjunct, we can scarcely endure the name of rewards; they seem to us to be no better than bribery. We would rather a child should be taught to perform a good action, or submit to a necessary privation, because it will bring with it its own reward, its own peace and tranquillity of mind. Those who encourage the baneful and pernicious practice of rewards, must surely believe in the omnipotent power of bribery. The late Dr. Macnish has some sensible observations on this practice, in a note to Dr. Brigham's Treatise on Health:—" The detestable practice of bribing children to do anything—however good or necessary in itself—cannot be too soon abandoned. It fosters habits of intense selfishness and greed—destroys every kindly and generous feeling in the young mind, and makes the child a base, grasping, and avaricious creature. Some children are, by their parents, bribed to go to school, to take medicine, or even to speak the truth. If a child is properly brought up, and has arrived at the period when it can comprehend parental authority, no lure whatever is required to make it do what is right. The word of a parent should be to it a law, which it would hardly dare to disobey. Whenever children above four years of age are turbulent, disagreeable, and unmanageable, the fault, with very few exceptions, and those arising from malformation, will, in almost every instance, lie with the parent."

In adults, this sentiment in too great activity, besides inducing a love of power, already alluded to, leads to contempt of the talents and capabilities of others. As Mr. Combe has aptly observed, it leads the individual to believe, that whatever he says or does is admirable, just because it proceeds from him.

This description of egotism, or inordinate Self-Esteem, is exceedingly prominent in the writings of the late Mr. Cobbett. There is a perpetual introduction of the pronoun *I*.

With the pronoun *I*, the curl of the lip, the toss of the head, the raising of the superciliary ridge, is associated Self-Esteem in its most prominent exercise; and then it is that the Alpha and Omega of selfishness and egotism are most graphically displayed. To *me* and *mine* is attached a great deal more consequentiality than to *thee* and *thine*. *My* views, *my* opinions, and *my* conclusions are altogether indisputable, and absolutely unexceptionable. Here is an instance in point:—

Macdonald, the last of the Lords of the Isles, was on one occasion invited to dine with the Lord Lieutenant of Ireland. Happening to go in late, he sat himself down at the lower end of the table. His Lordship, who knew his pride, sent a servant to invite him to move to the head of the table. Macdonald asked in his own tongue what the carle said. He was told his Lordship requested that he would move to the head of the table. " Tell the carle," said he, " that where Macdonald sits, THAT IS THE HEAD OF THE TABLE."

Thus, if the faculty be too large, the individual invariably considers himself some great one. On the contrary, if it be too small, the individual underrates his talents, and feels a most uncomfortable sensation of inferiority in the presence of others. This causes awkward and bashful movements of the body, hesitation and fear in speaking; especially if with the small Self-Esteem is associated much Cautiousness or Secretiveness. He in whom Self-Esteem is very large, is also less devotional and pious than others. The safest development of this organ is what phrenologist's denominate rather large—that is, a mean between full and large.

11. LOVE OF APPROBATION.—While engaged in the hospitals in establishing my discovery of the organ of Self-Esteem (says Dr. Gall, Works, vol. iv., p. 184), I met with a woman who imagined herself to be the Queen of France. I expected to find the organ of Self-Esteem large, but instead of the long oval prominence on the superior, posterior, and middle part of the head, I found a very distinct hollow, and on each side of it a pretty large round prominence. At first, this circumstance embarrassed me. I soon perceived, however, that the character of this woman's insanity differed materially from that of men alienated by pride. The latter were serious, calm, impetuous, elevated, arrogant; and they affected a masculine majesty. Even in the fury of their fits, all their motions and expressions bore the impress of the sentiment of domination, which they imagined themselves to exercise over others. In persons insane through vanity, on the other hand, the whole manner was different. There was then a restless frivolity, an incessant talkativeness, the most affected forwardness—eagerness to announce high birth and inexhaustible riches, promises of favour and honour—in a word, a mixture of affectation and absurdity. From that moment I corrected my ideas relative to pride and vanity.

The proud man is imbued with a sense of his own superior merit, and from the summit of his grandeur treats all other mortals with contempt or indifference. The vain man attaches the utmost importance to the opinions entertained of him by others, and eagerly seeks to obtain their approbation. The proud man expects that people will come to him, and find out his merit. The vain man knocks at every door to attract attention, and supplicates for the smallest portion of honour. The proud man despises those marks of distinction, which on the vain confer the most perfect delight. The proud man is disgusted by indiscreet eulogium. The vain man inhales with ecstasy the incense of flattery, however awkwardly offered. The proud man never descends from his grandeur, even in circumstances of the most urgent necessity. The vain man, to gain his ends, will humble himself even to crawling. Pride and thirst of domination are the traits of a few individuals, while the domain of vanity extends at least in a certain degree to every member of the human family. This may be sufficient to show that pride and vanity, the former an excess of Self-Esteem, the latter an excess of Love of Approbation, are two very different fundamental qualities, and must admit a primitive organ for each. In its legitimate exercise, Love of Approbation makes us attentive to the opinion entertained of us by others, and in this sense it is eminently beneficial. Who that has any regard for his standing and character in society, would not feel happy when he discovers his efforts meet with the approval of the wise and good? Who would stake his health, his credit, and life itself, in the defence of country, or in the rectification of abuse, if he knew that he should only receive contumely, or acquire an ill name? Why does the pale student,

" With aching head,
Ply his dull task, till sense and thought are fled,"

but to secure the good opinion of those for whom he entertains affection and regard? Contemplate the politeness and the suavity of the gentleman; behold the impassioned gestures, and attend to the still more impassioned language of the orator; study even the most striking appeals of the preacher, and Love of Approbation animates them all. Properly controlled by the superior sentiments, and guided by intellect, it is one of the most useful of the sentiments.

In almost all men of enterprise, Love of Approbation will be found fully developed. In the superior engravings of Columbus, Captain Cook, and the lamented Landers, the parts corresponding to this sentiment will be found prominent, distinguishing the power of the organ by the breadth of the head. But the direction the organ takes, depends on the combination of other faculties, and the education the person has received. Where the education has been neglected, and the animal propensities predominate, it has manifested itself in the desire, if Combativeness was especially large, to be considered the best boxer. Prize-fighters have often been known to endanger life itself, rather than lose their unenviable notoriety. Where Acquisitiveness prevails, and Love of Approbation is very large, there is ambition to be the robber chief. Burns illustrates this sentiment in the hard drinker, when he says,

" Wha last beneath his chair shall fa',
Shall be the king amang us a'."

The organ bears a variety of names, as ambition, vanity, vain-

glory, a love of notoriety, a love of distinction, and by several other epithets depending upon the strength of the faculty, and the various objects to which it is directed. As already remarked, it is of itself a noble feeling, though it may be, and often is, indeed, prostituted to the most ignoble pursuits and habits. The love of praise is so congenial, and so powerful a spur to every undertaking, that the moral world would be a complete chaos without its animating influence. The lines of the poet, Young, are beautifully expressive of this sentiment:—

"The love of praise, howe'er concealed by art,
Glows more or less, and reigns in every heart;
The proud, to gain it, toils on toils endure;
The modest shun it—but to make it sure;
It aids the dancer's skill, the writer's head,
And heaps the plain with mountains of the dead.
Nor ends it here: it nods with sable plume,
Shines on our hearse, and glitters on our tomb."

Love of Approbation is now more cultivated than formerly, and is addressing itself to the working classes, on the dignity of labour, the independence of toil, and after more peculiar styles. At one time, all the luxuries of life were considered the exclusive property of the rich; but now we have "pine apples" for the million, "concerts for the million," and there seems to be no end of "soft sawder" for the million.—all which things were, half a century ago, supposed to be very unbecoming, if not criminal, indulgences to the working classes, who humbly left them to their betters. In those days, flattering a great official was an infallible mode, as flattering the multitude is now; both are abuses of the sentiment of Love of Approbation. It is against flatterers that the working classes must be on their guard, if they wish to rise and become happier and wiser.

It is wonderful how this sentiment ramifies itself with others. There are many persons who become the more attractive and agreeable, the more eyes there are upon them; and this not from an excess of Approbativeness, but because general approval imparts confidence to them, and thus excites them to greater exertion. Others are far more pleasing when in the company of but one person, if their ideas and tastes agree. This much depends on the combination of faculties in connection with Love of Approbation. He who has good verbal memory (Language), who can give striking answers, and express his thoughts in elegant phraseology (Ideality), is a welcome companion in a large circle. He whose intellect is moderate, but who has much Imitation, combined with Adhesiveness and Love of Approbation, will be always admired by the ladies, and at tea-tables is the most assiduous in handing round the refreshments. These gentlemen are usually designated as ladies' men. So, again, he in whom there is a large Love of Approbation, combined with Ideality, Form, Size, and Order, and but moderate Intellect, will be found great as a leader of fashion.

We will only give one more illustration, which we think may prove a very useful lesson to mammas.

"Childish vanity should never be treated as a crime. In some instances, it might be advisable to let a child learn, by experience, the paltriness of the enjoyment arising from the gratification of it. For example:—C. was very vain of some jewels, the gift of an injudicious relative; she emphatically called them her *doo-ills*. Day after day she asked to wear them; day after day, her mother said 'No;' but finding that the refusal was of no use, she was puzzled what course to adopt, until it occurred to her to let one fire put another out. Accordingly, the next time C. applied to her to let her wear her *doo-ills*, she answered, 'Certainly, wear them if you please; but you know these things are valuable, because your mamma's dear friend gave them to you. They must neither be lost nor spoiled. If you have them on, you must remain in this room, and even, I think I should say, upon this chair, in order to be sure they are safe.' C. consented to the terms, and joyfully bedecked herself with her finery, and then stationed herself upon a chair. It was a fine evening in August, and the other children were out: however, for two hours C. persevered in sitting on the chair. At length she begged to have them taken off, and from that time to this (two years) the *doo-ills* have never been mentioned but with an uncomfortable feeling, and a blush.

"The plan here adopted answered very well to check vanity in that direction; but against vanity about dress, and all other things, there is but one real remedy, the substitution of love of excellence for love of excelling; the development of the intellect also will bring about a just appreciation of the value of dress, &c., when weighed against mental superiority."*

GEOGRAPHY.

CHAPTER VII.

SUBDIVISIONS OF EUROPE—COMPREHENDING A BRIEF SKETCH OF ITS DIFFERENT KINGDOMS.

THE BRITISH EMPIRE.—II. SCOTLAND.

HISTORICAL SKETCH.—The ancient name of Scotland was *Caledonia;* the Romans who invaded a great portion of it, A.D. 79, called it *Britannia Barbara;* in the eighth century it was called the country of the *Picts;* and it did not receive its present name until the eleventh or twelfth century. Like England, Scotland was originally peopled by the ancient Celts, who were here also in process of time driven to the *highlands*, or mountainous parts of the country, by the Saxons and other Gothic tribes who took possession of the *lowlands*.

The people called Scots first inhabited Ireland, which was therefore called Scotia, down to a comparatively late period; so that it would appear they were more powerful than the Hiberni, the previous inhabitants of that kingdom.

In the beginning of the sixth century, a colony of Scots came across from the north of Ireland, and settled in the district now called Argyleshire. To their newly-acquired territory they gave the name of Dalriada, after their leader Rieda, or Reuda. Here the Scots remained for more than two hundred years, while the rest of the island, north of the friths of Forth and Clyde, was occupied by the Picts in two divisions—the northern or highland Picts, and the southern or lowland Picts. Between these different occupants of the kingdom there were frequent wars, until the year 843, when they were united into one nation by Kenneth MacAlpin, originally king of the Scots. In the beginning of the tenth century we find the whole of North Britain under one king, and known by the name of *Albania*. At that period, Orkney and the Western Isles were possessed by the Norwegians, between whom and the successors of Kenneth there were frequent wars. About the middle of the tenth century, the Norwegians, under Thorfinn, grandson of a great warrior of the same name, acquired possession of the whole northern portion of the kingdom as far south as the Tay, and retained it for thirty years. King Duncan expelled the Norwegians from his dominions, but he was murdered by Macbeth, who usurped the sovereignty of the South, while his friend, Thorfinn, reigned undisturbed in the North until 1054. In that year a Saxon force drove Macbeth beyond the Forth and Clyde, and restored the crown to its rightful heir, Malcolm, the eldest son of Duncan; and in 1058, while Edward, king of England, was warring against Thorfinn and his ally Macbeth, the latter, in endeavouring to effect his escape to the North, was overtaken in Lumphanan, in Aberdeenshire, and slain by Macduff.

On the death of Thorfinn, in 1064, Malcolm, who was surnamed Canmore, got possession of the greater part of his kingdom; the remaining part, with most of the islands, fell into the hands of the native chiefs.

The principal chiefs who figured in Scottish history during the next four hundred years, were the earls of Moray, the earls of Ross, and a much more powerful opponent of the Scottish kings than either—the Macdonalds of the Hebrides, who styled themselves "Lords of the Isles." These Celtic chiefs exerted great influence in the North, and continued to be very formidable till the defeat of Donald, Lord of the Isles, at the battle of Harlaw, in 1411; there the strength of

* Monthly Repository.

these chiefs was first broken. and, in 1493, the property of the last lord was forfeited, and the title finally extinguished.

On the death of Malcolm Canmore, in 1093, the succession to the throne was disputed between Duncan, a natural son of Malcolm, whose claims were supported by the Lowlanders and Southerns, then for the most part Saxon—and Donald Bane, brother of the late king, who had the support of the Celtic tribes of the North. This dispute ended in the death of Duncan, and in the crown being placed upon the head of Edgar, his brother, by the aid of an English army; and although it was fully two centuries afterwards before the sway of the king of the Scots was completely established over the whole of Scotland, this event not only decided the principle of succession, but gave the Saxon an ascendancy over the Celt.

On the accession of Edgar, we find a Saxon population and Saxon institutions over the whole country south of the friths of Forth and Clyde, as well as over the territories to the north of these friths, which the Scots had wrested from the southern Picts. In short, the whole of Scotland, with the exception of that part of the kingdom of Thorfinn which remained in the hands of the native chiefs, exhibited an exact counterpart of Saxon England. The country was divided into earldoms, which were bestowed upon members of the royal family; Saxon thanes were introduced over the whole country, and sheriffs and sheriffdoms were everywhere established. It is from the reign of David I. that we are to date the introduction of Norman institutions into Scotland.

The most important events in Scottish history are the wars with the three Edwards of England, which abound with deeds of heroic valour, but in which BRUCE and WALLACE were by far the most distinguished among their patriotic countrymen. The period of the beautiful and amiable, but unfortunate and unjustly treated, Mary Queen of Scots, is a very interesting epoch of Scottish history; while the accession of her son James to the throne of England, joining the two kingdoms under one sovereign, was an event of the utmost consequence to both.

The succession of Scottish kings from Edgar, son of Malcolm Canmore, with a few of the most remarkable events, is as follows:—

Name and Genealogy.	Began to Reign.	Remarkable Events.
Edgar, *son of Malcolm Canmore*	1097	Reign mild and beneficent.
Alexander I., *his brother*	1107	Called Alexander the Fierce.
David I., *his brother*	1124	Promoted religion and all the peaceful arts.
Malcolm IV., *his grandson*	1153	Reign disturbed by civil broils.
William I., the Lion, *his brother*	1165	Reign peaceful and spirited.
Alexander II., *his son*	1214	One of the wisest of Scottish kings.
Alexander III., *his son*	1249	Nation was rich, tranquil, and flourishing under this good king.
Margaret, Maiden of Norway, *his grand-daughter*	1286	Died on her voyage to Scotland.
Interregnum	1290	King Edward of England aims at the Scottish crown.
John Baliol, *gt.-gt-gt.-grandson of David I.*	1292	Wars with Edward of England.
Interregnum	1296	Period of the heroic Sir William Wallace.
Robert Bruce, *gt.-gt.-gt.-gt.-grandson of David I.*	1306	Memorable battle of Bannockburn, and English expelled.
David II., *his son*	1329	Invasion by Edward of England.
Edward Baliol, *son of John Baliol*	1332	Ascendancy of England.
David II. *restored*	1341	Selfish king.
Robert Stuart, *grandson of Robert Bruce*	1370	Wars with England.
Robert III., *his son*	1390	Do.
James I., *his son*	1406	Was a good king, and possessed a highly cultivated mind.
James II., *his son*	1437	St. Andrew's University founded. King famous for his valour and clemency.
James III., *his son*	1460	Wars with England. Excellent and talented king.
James IV., *his son*	1488	Wars with England. Good and talented king.
James V., *his son*	1513	Wars with England. Good king.
Mary, *his daughter*	1532	Protestant Reformation. Queen Mary executed by her cousin, Elizabeth of England.
James VI., *her son*	1567	Union of the crowns of England and Scotland.

1. SUPERFICIAL FEATURES.—Scotland is divided into north and south divisions by the Grampians, a range of mountains which traverses the whole breadth of the island at about the 57th degree of north latitude, stretching from Fort-William on the west, to Aberdeen on the east coast. The northern division is again subdivided into two parts by the great glen, or Glenmore, which, passing through several long lochs, forms the line of the Caledonian canal, and stretches from Fort-William to Inverness. The southern division of Scotland is also subdivided into two parts by a valley, which stretches from the frith of Clyde on the west, to the frith of Forth on the east coast; on the south of this boundary lies the South of Scotland, properly so called, and on the north, Central Scotland.

To the north-west of the great glen is the most sterile portion of the island; it consists, in a great part, of a very extensive plain, varying from 500 to 1,500 feet above the level of the sea, and consisting, in general, of barren rocks and mountain masses. Its north and west extremities terminate in abrupt declivities on the sea-coast; but on the east and north-east side, towards the friths of Dornoch, Cromarty, and Moray, the plain becomes, in most parts, lower and more susceptible of cultivation. The surface of this district is cut by many long, deep, and narrow valleys, in the bottom of which the streams run. The inhabitants are few and thinly scattered, and the soil, over the greater portion of the district, produces nothing but pasturage for sheep.

The district between the great glen and the Grampians is divided into two parts by the Cairngorm mountains; the western section is a mountain plain, frequently presenting an irregular and hilly surface, and is mostly composed of heath and pasture land; it comprehends the upper districts of the principal rivers. The north-eastern section, although in many parts hilly (except towards the sea-coast), presents in general a well-cultivated and tolerably fertile country, all over the lowlands of Aberdeen, Banff, and Moray shires.

The western portion of central Scotland, which commences on the south side of the Grampians, is generally sterile and unproductive, much intersected by lochs and arms of the sea, and abounds in wild and picturesque scenery. The eastern portion of this region, commencing among the mountains in valleys of considerable fertility, stretches out into a level, rich, and beautifully cultivated country, comprehending the fertile plain of Strathmore—eighty miles long, from Stirling to Stonehaven—the plains of Fife, Kinross, and Clackmannan.

Although southern Scotland is in many parts hilly and even mountainous, it wants the rugged barrenness of the north, most of the hills affording pasture for sheep, while we have many extensive plains and valleys of the richest and best cultivated soil in Britain.

2. CLIMATE.—The climate of Scotland, though variable and more severe than that of England, is, on the whole, mild and salubrious. Its western side is affected with moisture and humidity, being exposed to heavy rains from the Atlantic, while its eastern coast, though drier, suffers more from cold east winds and chilling fogs from the German Ocean. "But," says Maculloch, "owing to the proximity of most parts of the country to the sea, and the numerous friths and deep bays by which it is penetrated, it is less severe than might, from the latitude, be expected. The mean annual temperature of places near the level of the ocean, throughout the country, averages about 46½ degrees of Fahrenheit. At Edinburgh, which is from 300 to 400 feet above the sea-level, the mean temperature of the year is 47 degrees 8 tenths, which may be taken as that of the inland parts generally in the south of Scotland, the mean of the coldest month being 38 degrees 3 tenths, and of the warmest, 59 degrees 4 tenths." The annual fall of rain ranges, on the east coast, from 22 to 28 inches; on the west coast, from 30 to 44. The average in Edinburgh is 23½ inches; in Glasgow, about 29·65 inches. August, September, and October, are the rainy months on the west coast; April, May, and the first half of June, are much affected by cold piercing east winds on the east coast.

3. MOUNTAINS.—From what has been already said of its superficial features, it will be seen that Scotland is, in general,

a mountainous country. The principal mountain ranges and groups are:—

1. *Those North of the Great Glen, or of the Caledonian Canal.*

Names and Positions.	Heights in feet.
Ben Wyvis (*Ross-shire*),	3,720
Ben Atlow *do.*	4,000
Ben More *do.*	3,551
Ben More (*Island of Mull*),	3,168
Cuchullin (*Island of Skye*),	2,995
Hecla (*South Uist*),	2,940
Clisseval (*Island of Lewis*),	2,700
Mount Rona (*Shetland*),	1,470

2. *The Grampian Range.*

Names and Positions.	Heights in feet.
Ben Macdhui (*Aberdeenshire*),	4,390
Ben Nevis (*Inverness-shire*),	4,370
Ben Lawers (*Perthshire*),	3,945
Ben Lomond (*Stirlingshire*).	3,191
Cairngorm (*Aberdeenshire*),	3,900
Cairntoul *do.*	4,220
Lochnagar *do.*	3,815
Mount Keen *do.*	3,126

3. *The Central or Lowland Group.*

Names and Positions.	Heights in feet.
Sidlaw Hills (*Perthshire and Forfarshire*),	1,406
Ochills, Ben Clach (*Clackmannanshire*),	2,359
Pentland Hills (*Edinburghshire and Lanarkshire*),	1,860
Lammermuir Hills, (*Haddingtonshire*),	1,700
Mistie Law (*Renfrewshire*),	1,558
Campsie (*between the Forth and Clyde*),	1,220

4. *The Cheviots, with their continuation, the Lowthers.*

Names and Positions.	Heights in feet.
The Lowthers (*Lanarkshire*),	3,150
Queensberry Hill (*Dumfriesshire*),	2,259
Hart Fell (*Dumfriesshire and Peeblesshire*),	2,635
Ettrick Pen (*Selkirkshire*),	2,258
Cheviot (*between Roxburghshire and Northumberland*),	2,658
Cross Fell (*between Roxburghshire and Cumberland*),	2,901

4. Plains.—From the limited extent and mountainous formation of the country, it is not to be expected that there would be any great plains. Between the mountain ranges, however, there are many valleys, denominated carses, straths, haughs, and dales, all under rich cultivation. The chief of these are, Strathmore, stretching through Perth, Forfar, and Kincardine shires, and lying between the Grampians and the Ochill hills; the Carse of Gowrie, on the north of the Tay; Strathearn, extending along the course of the Earn to its junction with the Tay; the Carse of Stirling and Falkirk, in the valley of the Forth; the Howe of Fife, lying along the Eden; Clydesdale; the Merse of Berwick; and the Howe of Buchan, in the north-eastern portion of Aberdeenshire.

5. Lakes or Lochs.—The numerous *lochs*—for which Scotland is celebrated, and which add so much to its picturesque and beautiful scenery—are chiefly situated in the north-western, or *Highland* region of the island. There are few of any size in the south, and still fewer in the central or *Lowland* district. The following are the principal *lochs* in the different regions:—

1. *In the North-Western or Highland Region.*

Loch Lomond	Between Dumbarton and Stirlingshire	Largest lake in Britain	Has beautiful scenery, and studded with more than 30 islands.
Loch Awe	In Argyleshire	25 miles long; 1 to 2 broad	Beautiful lake.
Loch Lydoch	do.	Large	Less beautiful.
Loch Shiel	do.	Large	
Loch Ness	In Inverness-shire	22 miles long	Caledonian canal passes through it.
Loch Laggan	do.	8 miles long	
Loch Ericht	do. and partly in Perthshire		
Loch Arkaig	do.	8 miles long	Wild scenery.
Loch Quoich	do.	5 miles long	Rugged scenery.
Loch Maree	In Ross-shire	Very large	do.
Loch Fannich	do.	Small	do.
Loch Shin	In Sutherlandshire	14 miles long; 1 to 2 broad	
Loch Naver	do.	Small	
Loch Hope	do.	do.	
Loch Katrine	In Perthshire	8 miles long; 1 broad	Picturesque scenery of the Trossachs.
Loch Voil	do.	Small	
Loch Earn	do.	5 miles long	Beautiful lake.
Loch Tay	do.	15 miles long; 1 to 2 broad	do.
Loch Rannoch	do.	10 miles long	On branch of Tay.
Loch Tummel	do.	Very small	On same river.
Loch Garry	do.	do.	

2. *In the Southern Region.*

Loch Ken	In Kirkcudbrightshire		Into which flows a river of the same name.
Loch Cree	In Wigtonshire		
Loch Doon	In Ayrshire	Small	Source of river Doon.
St. Mary's Loch	In Selkirkshire	4 miles long	A beautiful lake.

Loch Leven, in Kinross-shire, is the largest loch in the central or Lowland district of Scotland; it contains four islands, on one of which are the ruins of Loch Leven castle, celebrated for its historical associations as the prison of Queen Mary.

Besides these *fresh-water* lakes, there are many arms or indentations of the sea, penetrating the land, particularly on the west coast, which are denominated lochs, such as Loch Long, Loch Fine, Loch Etive, Loch Linnhe, &c.; but these are, properly speaking, friths or arms of the sea.

6. Rivers.—Proceeding from many of these fresh-water lochs, there are numerous rivers, but few of them of any magnitude, and they have almost all very different features from the English rivers. Instead of the slow and winding course, bounded on each side by fertile and level vales, which are the characteristics of the English rivers, most of those of Scotland descend from rugged and precipitous mountains, are rapid in their course, cut deep channels in their path, and, with few exceptions, are of no use for internal navigation.

The following are the principal rivers, beginning on the east coast, their directions, the counties through which they flow, their lengths, and the chief towns on their banks:—

Name and Direction.	Counties through which they flow.	Length in Miles.	Chief Towns on their Banks.
Findhorn, N.E.	Inverness-shire and Nairnshire	80	Forres.
Spey, N.E.	Inverness-shire and Elginshire	85	Fochabers.
Deveron, N.E.	Aberdeenshire and Banffshire	40	Huntly, Turriff, Banff.
Don, E.	Aberdeenshire	60	Inverury, Old Aberdeen.
Dee (*north*), E.	do.	80	Aberdeen, Banchory, Ballater.
North Esk, E.S.E.	Forfarshire	30	
South Esk, E.	do.	40	Montrose, Brechin.
Tay, E.S.E.	Perthshire	150	Perth, Dunkeld.
Earn, E.	do.	40	Crieff, Bridge of Earn.
Forth, E.	Perthshire and Stirlingshire	115	Stirling, Alloa.
Clyde, W.N.W.	Lanarkshire, Dumbartonshire, Renfrewshire	100	Glasgow, Renfrew, Dumbarton.
Tweed, E.N.E.	Peeblesshire, Selkirkshire, Berwickshire	100	Coldstream, Melrose.
Teviot, N.E.	Roxburghshire	35	(branch of Tweed) Hawick.
Nith, S.E.	Dumfriesshire	60	Dumfries.
Dee (*south*), S.	Kirkcudbrightshire	60	Kirkcudbright.

The only rivers among these which are navigable, are, the Tay, the largest, navigable to Perth; the Forth, navigable to Stirling, for vessels of 70 tons; and the Clyde, navigable to Glasgow.

7. Bays, Gulfs, and Straits.—From the numerous indentations of the sea upon the coast of Scotland, and the number of islands on the north and west coasts, there are a great many intricate *Bays*, *Gulfs*, or *Friths*, and *Straits*, on all sides of the kingdom, the principal of which are the following:—

The Pentland Frith—between Caithness and the Orkney Islands.

Dornoch Frith—a large expanse of water, between Sutherland and Ross.

Cromarty Frith—between Ross and Cromarty; would form a splendid harbour.

Moray Frith—between Ross and Inverness, and Nairn and Moray shires.

Frith of Tay—between Fife and Forfar and Perth shires; navigable for large vessels to Dundee.

Frith of Forth—between Fife and the Lothians, running inland for fifty miles, navigable for ships of any burden to Alloa, and containing numerous harbours, where ships take shelter in the storms which ravage the German Ocean.

Solway Frith—separating the counties of Dumfries and Kirkcudbright from Cumberland.

Wigton Bay—between Kirkcudbright and Wigton.

Luce Bay—in the south of Wigtonshire.

Loch Ryan—in the north-west of Wigtonshire.

Frith of Clyde—separating Ayr and Renfrew from Bute, Argyle, and Dumbarton shires; an important and beautiful frith, containing several picturesque lochs; it is navigable for large vessels as far as Glasgow Bridge.

Loch Long—between Dumbarton and Argyle.

Loch Fine—in the south of Argyle.

Sound of Jura—between Argyle and the island of Jura.

Loch Etive, *Loch Linnhe*—in the north-west of Argqle.

Sound of Mull—between Argyle and the island of Mull.

Loch Broom—in the north-west of Ross-shire.

Minch—separating the mainland and the isle of Skye from Lewis.

8. Capes.—The *Capes*, or, as they are denominated, "Heads" and "Nesses," are equally numerous; the chief of which are the following:—

On the East Coast.

Dunnet Head and Duncansbay Head—in Caithness.

Tarbet Ness—in Cromartyshire.

Troup Head—in Banffshire.

Kinnaird's Head and Buchan Ness—in Aberdeenshire.

Fife Ness—in Fifeshire.

St. Abb's Head—in Berwickshire.

On the South Coast.

Southerness—in Kirkcudbrightshire.

Barrow Head and Mull of Galloway—in Wigtonshire.

On the West Coast.

Corsill Point—in Wigtonshire.

Mull of Cantyre, *Mull of Oe, Point of Rinns*, *Point of Ardnamurchan*—in Argyleshire.

Butt of Lewis—in the north of Lewis.

Barra Head—south point of Hebrides.

Aird Point—in Skye.

Cape Wrath—in Sutherlandshire.

HORTICULTURE.

CHAPTER X.

THE MANAGEMENT OF FLOWER BORDERS.

In a garden, such as we have supposed, a number of the borders will be appropriated to flowers, and a portion near the house will probably be entirely dedicated to them and to shrubs. We proceed to enumerate the more important herbaceous bulbous annual flowers, and then to make some general remarks upon the cultivation of what are called florist's flowers. We are a good deal indebted in this chapter to Mr. Smith.

EARLY SPRING HERBACEOUS PLANTS.

		FOOT.		FOOT.	
Helleborus niger,	Red, from	½	to	1	
Helleborus lividus,	Green,	½	to	¾	
Eranthus hiemalis,	Yellow,			½	
Hepatica triloba,	Red,			½	
Primula vulgaris,	Red,			½	and other varieties.
Cortusa mathiola,	Red,	½	to	¾	
Soldanella alpina,	Blue,			½	
Viola—various kinds,	Various,			½	
Dodecatheon meadia,	White,	¾	to	1½	and other varieties.
Orobus vernus,	Purple,	½	to	1	
Adonis apennina,	Yellow,	½	to	¾	
Omphalodes verna,	Blue,	½	to	1	
Corydalis lutea,	Yellow,	½	to	1	
bulbosa,	Red,	½	to	1	
Bellis perennis,	Various,			½	
Iris livida,	Brown,	½	to	¾	
humilis,	Purple,			½	
Anemone apennina,	Blue,	½	to	1	
nemorosa,	White,	½	to	¾	
Hallerii,	Purple,	½	to	¾	
Sisyrinchium striatum,	Yellow,	¾	to	1½	

MAY HERBACEOUS PLANTS.

Anemone hortensis,	Variegated,			½	
sylvestris,	White,	½	to	1	
dichotoma,	White,	1	to	½	
Primula farinosa,	Blue,			½	
scotica,	Red,			½	
Convallaria majalis,	White,			½	
Uvularia grandiflora,	Yellow,	1	to	1½	
perfoliata,	Yellow,	½	to	1	
Phlox australis,	Blue,	½	to	1	
carolina,	Blue,	½	to	1	
Asphodelus luteus,	Yellow,	1½	to	2	
Draba aizoides,	Yellow,			½	
Viola cornuta,	Blue,			½	
obliqua,	Blue,			½	
Gentiana verna,	Blue,			½	
acaulis,	Purple,			½	
Lupinus polyphyllus,	Blue,			2	and often more.
Iris hungarica,	Purple,	½	to	1	
chinensis,	Blue,	1½	to	1	

JUNE HERBACEOUS PLANTS.

Pœonia officinalis,				
albiflora,				
corillina, &c.				
Dianthus, var. species,	Variegated.			
Geranium sanguineum,	Red,	½	to	1
nemorosum,	Purple,	1	to	1½
pallidum,	Blue,	1	to	1½
Monarda didyma,	Red,			3
Papaver bracteatum,	Red,			3
Saxifraga, var. species,	White, &c.	1	to	2
Spiræa, various species,	Pink, &c.	1½	to	5
Mimulus ringens,	Lilac,			1
glutinosus,	Orange,			½
moschatus,	Yellow,			1
Trollius americanus,	Yellow,			1
europæus,	Yellow,			1
Hysimachia virtiullati,	Yellow,			1
Veronica latifolia, &c.,	Various.			
Geum coccineum,	White,	1	to	1½
Aconitum napellus,	Dark,			4
Potentilla nepalensis,	Purple,	1	to	1½

JULY HERBACEOUS PLANTS.

Phlox intermedia,	Pink,	2	to	3
Pentstemon, va. species,	Various.			1
Œnothera, do.	do.			
Campanula, do.	do.			
Asclepias amœna,	Purple,			3
syriaca,	Purple,			4
Iris fulva,	Yellow,			2
pallida,	Lilac,	1	to	2
variegata,	Striped,			2

PLATE C

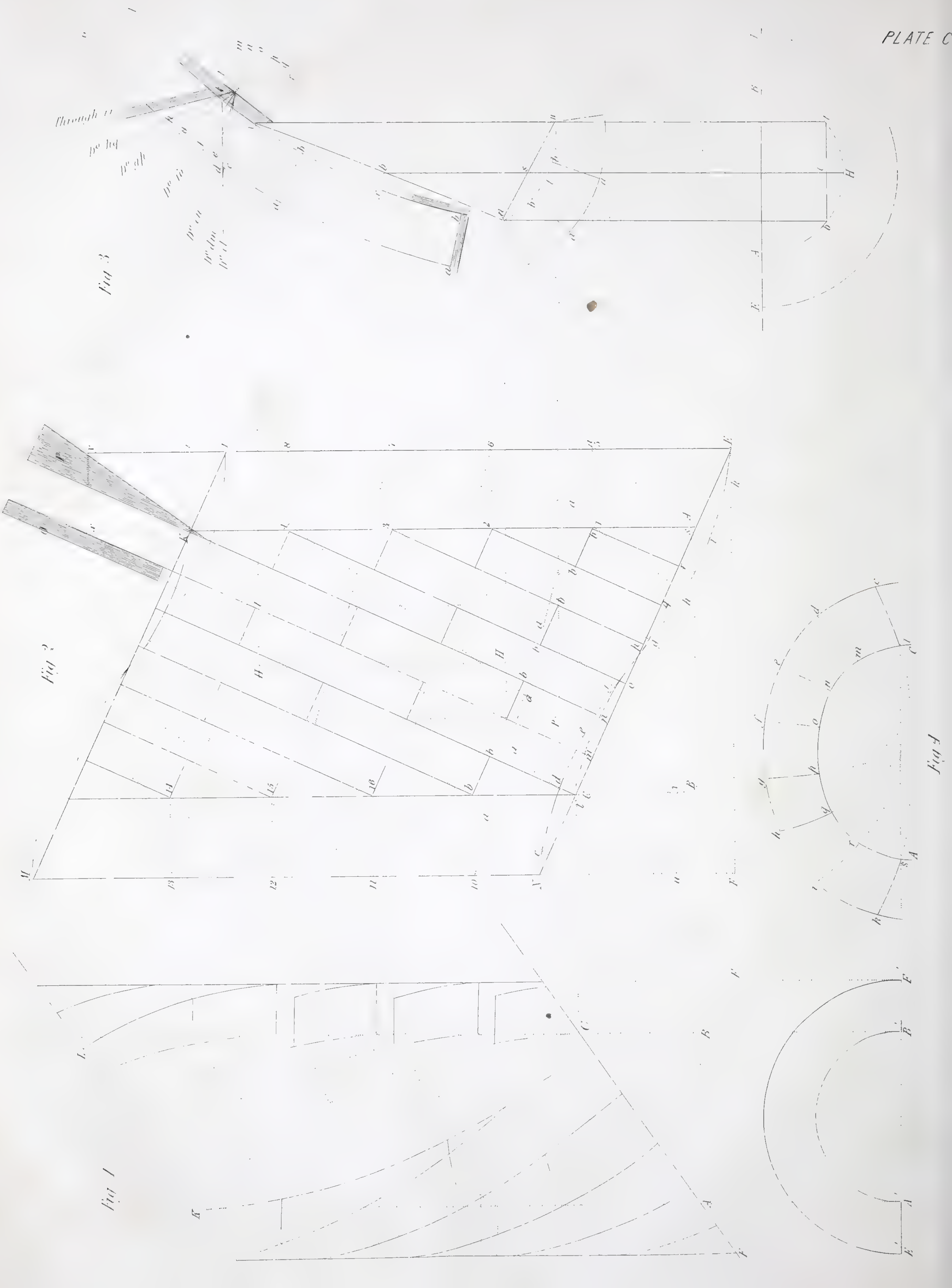


PLATE I

Fig 1

Scale 1/8 = 1 Ft

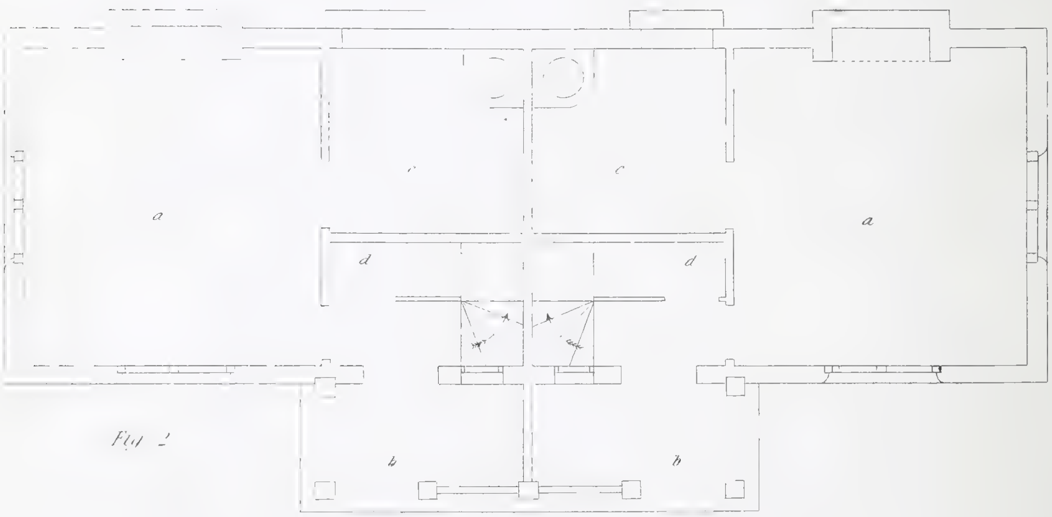


Fig 2

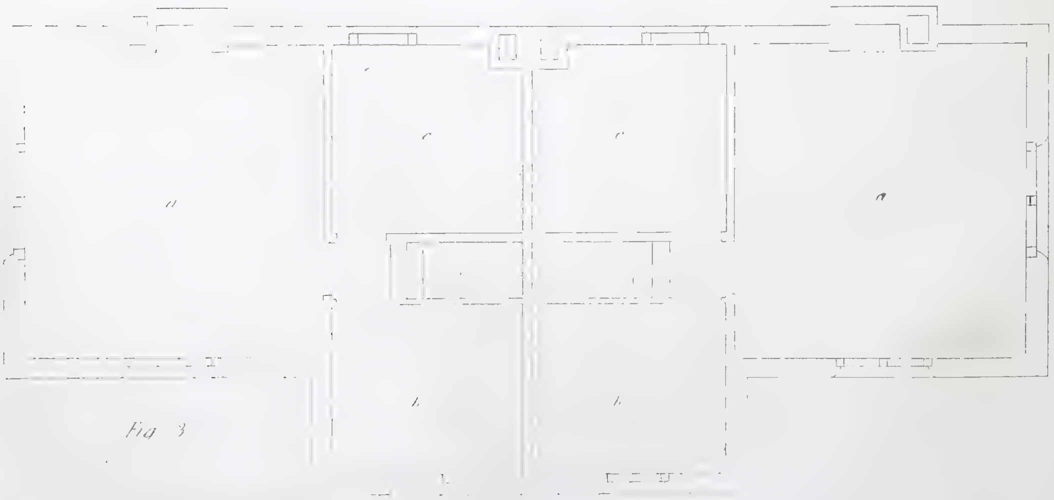


Fig 3

AQUATIC PLANTS.

A little sheet of water is a very beautiful ornament to a garden. The following plants will grow and flower in the water, and look very pretty. The usual mode of propagating them is by dividing the roots.

Aquatic Plants that Flower in May.

Equisetum fluviatile,	Red.	
Calla palustris,	White.	
Myriophyllum spicatum,	Blue.	
Lysimachia thyrsiflora.	Yellow.	
Peplis portula.	Purple.	

Aquatic Plants that Flower in June.

Equisetum palustre,	Red.	
Villarsia indica,	White.	
caudata,	Yellow.	
Nymphæa alba,	White.	And two following months.
odorata,		
Myriophyllum spicatum,	Blue.	

Aquatic Plants that Flower in July.

Nymphæa nitida,	White.
Nuphar advena,	Yellow.
sagittæfolia,	Yellow.
Hippuris vulgaris,	Red.

Aquatic Plants that Flower in August.

Hydropeltis purpurea,	Red.
Potamogeton natans,	Yellow.
Nuphar pumila,	Yellow.
Poa aquatica,	White.
Cicuta virosa,	White.

THE BUILDING ARTS.

CHAPTER I.

EXAMPLE OF SPECIFICATION FOR A SEMI-DETACHED HOUSE.

Under the above title we propose giving a series of papers on the various branches of the mechanical arts, connected with practical architecture. The subjects will be treated of under distinct divisions, comprising:—1st, Foundations, drains, &c.; 2d, Limes, cements, mortars, concretes; 3d, Bricks and brick-setting; 4th, Stones and masonry; 5th, Carpentry and joining. While carefully pointing out the indications afforded by established theory, the great aim of the essays will be to furnish in a condensed form a large amount of practical information, arranged also in such a way as to be at once available for the purposes of reference and afford a guide in practice.

Some idea of the nature of our proposed papers may be derived from a perusal of the following analytical sketch of the subjects intended to be treated of:—

I. Foundations under ordinary circumstances; footings; ditto in yelding soils; planking; piles; concrete; beton; sand foundations; foundations under water, &c. Drains, laying out of; form of; fall. Theory as regulating the practice of drainage; constructions, junctions, traps, &c.

II. Chemical action of Limes—burning or calcination of limes; different varieties of limekilns; hydraulic limes; character of limestones available for ditto; artificial hydraulic limes; method of making ditto; slacking or slaking of limes, different modes of. Mortar—different kinds of sand used in making mortar; pit, river, and sea sand. Properties of sand to be used:—concrete, beton; adhesive properties of mortar; estimated amount of force of ditto, with different materials. Cements—Portland, Roman, bituminous cements, plaster, "parian," "keenes," colour washes for external walls, ditto for internal.

III. Bricks—brick earth, different kinds of; their constituents and value for brick-making; implements used in brick-making; tempering; moulding; drying; firing; brick-kilns; brick-setting. Different kinds of "bond," Flemish, Old English, hollow brick-work; different methods of erecting walls in ditto, for nine inch, eleven inch, and fourteen inch walls; "British" bond; patent hollow bricks; carrying up of walls. Different forms of arches, fire-places, flues, &c. Practical hints on brick-setting.

IV. Different kinds of Stone used for building purposes—granite, limestone, sandstone, &c. Quarrying stone, blasting, boring, loading, tamping, firing. Tools used in masonry. Facing up of stones; designs for cornices, window sills, &c. Carrying up of walls in masonry; foundations; bond; laying of stones, &c.

V. Carpentry, &c.—different kinds and qualities of timber useful for the purposes of framing; preserving of timber in damp situations; theory of framing; practice of ditto; joints; "half-lap," "scarf," "dovetail," &c. Wall-plates; flooring joists; single flooring; double flooring; trimmers; partitions; roofs; designs for joining of timbers for roofs, partitions, &c.; staircases; stairs. Joining—designs for cornices and architraves; base mouldings; doors; windows; chimney-pieces, &c.

Domestic edifices may be comprised under three divisions: 1st, Street houses, including shop fronts; 2d, Suburban; 3d, Rural. In the second division the houses generally constructed belong to two classes: semi-detached (that is, two houses in connection), and detached or single, these being either of the class of villas or cottages. In rural districts, the houses are generally detached, being mansions, villas, or cottages. We propose giving working drawings of houses, cottages, &c., forming examples of the classes above specified.

In Plates I. and II. we give full working drawings (reduced) of a design for a semi-detached house for a suburban district; these comprise *basement* or *cellar* plan, drawn to a scale of one-sixteenth inch to a foot. The following are the dimensions of the various apartments, as figured in Plate II.:—A, the larder, eighteen feet seven inches by fourteen feet six inches; B, the drying-room, eighteen feet nine inches by fourteen feet six inches; C, the washing-house, fourteen feet six inches by thirteen feet nine; D, the wine-cellar, eight feet by five feet six inches; E, the cellar-stores, thirteen feet seven inches by seven feet two inches; H, the coal-cellar, eight feet five inches by four feet three inches. *Ground plan*, (scale for ground and chamber plans in Plate I., "scale for figs. 2 and 3.") A is the drawing-room, nineteen by fifteen feet; B, the dining-room, nineteen feet by fourteen feet nine inches; C, the kitchen, fourteen feet nine by fourteen feet, *b* the dresser, *c* a cupboard; D, the breakfast-room, thirteen by twelve feet; E, the scullery, ten feet nine inches by seven feet six inches; *a* is the slop stone; F, the pantry, eight feet six inches by four feet three inches; H, lobby, five feet six inches wide. *Chamber plan*, a principal bed-room, nineteen by fifteen feet; dining-room, twelve feet by five feet six inches; B, bed-room, nineteen feet by fourteen feet nine inches; C, bed-room, fourteen feet by fourteen feet nine inches; D, bed-room, thirteen by twelve feet; F servant's bed-room, (or bath-room if required,) ten feet nine inches by seven feet six inches. The other drawings consist of front elevation (Plate I.), drawn to a scale of one-eighth inch to the foot; back elevation (Plate II.); side elevation drawn to same scale as sections in Plate I. Fig. 3, Plate I., is a transverse section through scullery, breakfast-room, lobby, and drawing-room. Fig. 2 is a longitudinal section of one house through drawing and dining-room.*

The specification is a most important document, and one which requires the greatest care in drawing up.

The following is an example of a specification, with the usual conditions and stipulations. This is the specification of the house of which the drawings are given, in Plates I. and II.

GENERAL CONDITIONS.

The several contractors for these buildings will have to provide the whole of the materials, tools, tackle, and every other requisite for completing the work. The whole of the materials and workmanship (herein provided) to be the very best of their several kinds, sound and well-seasoned; and to be applied in the most workmanlike and substantial manner under the direction of the architect, and to his and the proprietor's entire satisfaction. The drawings are strictly to be attended to, and considered equally binding with this specification; and should anything appear to have been omitted in either the plans or specifications, or both, which is usually considered neces-

* In Plate III. we give working detailed drawings, with references attached, of various important portions of the above example.

sary, and may be reasonably inferred in and from the said plan and specification, the contractor shall not obtain any advantage therefrom, but shall find and supply whatever materials or labour, or both, may be wanting to complete the whole of the works according to the true intent and meaning of the said plan and specification and general conditions; and the directions for their correct performance, as given from time to time by the architect, are to be strictly adhered to.

Any dispute or disputes that may arise in connection with, and during the performance of, the works, whether on account of extra or unfinished works of the drawings or specification or otherwise, of whatsoever kind, shall be referred to the said architect, whose decision or valuation, as the case may be, in writing, shall be binding and final to all parties.

Any extra work that may have to be done, is to be contracted for before commencing the same; and in the event of any of the contractors omitting such previous agreement, the architect shall measure and value the same at such prices as he deems the contractor has founded his tender upon, and the amount so valued shall be deducted from the sum due to the contractor.

The payments to the bricklayer, mason, and carpenter, to be made in three instalments, in sums not less than twenty per cent. upon the amount of the respective contracts, upon producing a certificate from the architect, that the amount of the sum applied for and received, does not exceed three-fourths of the value of the work then executed and performed, the value to be computed after the same ratio at which the architect conceives each contractor's tender or estimate has been formed.

The plasterer, slater, and plumber, to be paid when the whole of their work has been completed.

In case any other arrangement is thought desirable to be made, the same shall be fully specified in the written agreement, signed by the several contractors, and that agreement shall be final.

The proprietor, through his architect, reserves to himself the power of making any alterations or additions to the several works as they proceed, without nullifying or invalidating the contracts; but the architect will not feel himself bound by any order given, or which may be said to have been given *verbally*, for any such alterations and additions; and consequently, no allowance will be made for any such work, except the contractor or contractors can produce a *written* order from the architect.

The building, the ground attached, and the materials placed there, from the commencement to the finishing thereof, are to be considered in the possession of the proprietor, without tending to make void or invalidating any of the foregoing conditions, or making him liable to any accident, risk, or damage whatsoever, that may occur to the same; and no material to be removed without the architect's permission.

Should any of the contractors perform or provide any improper and untradesmanlike workmanship or materials, they shall be immediately replaced upon the architect requiring the same; and should any of the said contractors refuse to alter the same within twenty-four hours after a written notice has been given, it shall be lawful for the architect to relet the work to other contractors, and cause to be replaced with good and proper materials the said defective materials and workmanship, according to this specification, at the cost of the said original contractor or contractors whom it may concern.

From the commencement to the finish of every part of the respective works, the care of the same, and whatsoever appertains thereto, is to be with the several contractors, who are each in their respective departments to protect and preserve the same; and in case of any damage or injury happening to any portion of the said works by the artificers employed, by the inclemency of the weather, by fire, or by any accident whatever, the contractor or contractors whom it may concern shall repair the same at his or their cost, so that at the conclusion of the several works every part may be complete and perfect.

No portion of the works will be allowed to be sublet on any account, unless the architect shall fully approve of the same.

The buildings are to be erected, ready for the slater and plumber, in weeks from the date of an order from the architect to commence; in default of which, the bricklayer, mason, and carpenter, are, all and each of them, severally to pay to the proprietor the sum of shillings per week for each and every week, until the work shall be so built up from the aforesaid date, anything to the contrary whatsoever notwithstanding, to be recovered from them as and for liquidated damages, or to be deducted from the amount due to the said contractors. The whole of the slating and plumbing to the roofs, cornices, cisterns, and gutters, are to be thoroughly finished and completed in days after an order has been given by the architect to commence; in default of which, the plumber and slater shall, each and both, pay the sum of shillings per day to the proprietor, for each and every day, until the said work shall be completed, from the amount due to the said contractors. The whole of (*the work*) to be entirely completed to the full extent herein specified, in weeks after the roof is covered in; in default of which the contractors are all and each severally (except the slater) to forfeit and pay to the aforesaid proprietor the sum of for each and every week, until the aforesaid work shall be so completed from the aforesaid date, to be recovered from them, as and for liquidated damages, or to be deducted from the amount due to the said contractor or contractors. Each contractor to clear and cut away the rubbish accumulated from time to time in connection with his work, as the architect shall direct.

The several contractors are to be prepared with the names and residences of two respectable sureties each, at the signing of the contract.

BRICKLAYER.

The foundation and cellar walls, with the base course of bow windows, to be fourteen inches thick. The remainder of the external cellar walls to be the thickness specified, or shown for the walls above the same. The front and two ends to have cavity walls eleven inches and a half thick, fenced with the very best stock bricks, set in putty, and close jointed, well pointed and dressed as possible. The remainder of the external walls to be ten inches thick, with one inch cavity, except where shown. All the walls, internal and external, to be built (of the several heights and thicknesses shown on the drawings) in the very best manner. The cavity walls to be bonded to the common work every three feet in every course. No part of the building is to be advanced more than three feet in height above the rest. No brickwork to be done in weather which the architect may deem unfit.

The mortar to be made of the best fresh burnt lime, and good, clean, sharp sand (river), free from all impurities, in the proportion of one part of lime to two parts sand; the mortar to be made on a brick or stone floor, and thoroughly mixed together, and kept free from dirt.

All the return and cross joints to be well flushed with mortar for the entire size of the brick, and every third course to be grouted.

All the front and end windows to have neat gauged best brick camber arches, fourteen inches deep.

All the back windows to have seconds brick jack-arches, nine inches deep, set in putty.

The slopstones to be set on neat seconds bull-nosed brick pillars. The bricklayer to make the recesses to the windows two and a half inches deep, where shown.

The whole of the firegrates to be set with good fire-bricks, above and below the grates, in the very best and most approved manner, as the architect shall direct.

To provide and well bed cavity chimney pots, at the value of shillings each, before being set, of an approved kind.

The larders, wash-houses, beer cellars, bins, wine cellars, and the passages, to be properly laid with red tiles, and run with quicklime, and to be left perfectly even and perfect at the completion of the works.

The coal cellars to be paved with brick set on edge, and run with lime.

To build foundation walls, and flush up to the stone facing to the front wall; build the privies, ash-pits, dung-pits, and step foundation walls, to front doors, as shown in the drawings.

Set all the flag steps and window sills throughout the building.

Provide two eighteen-gallons boilers, with grate and bars

complete, and set the same with seconds bricks and putty joints. Provide and set twelve cast-iron air grids, eighteen by nine inches, under the base course, at such places and in such manner as the architect may point out.

Set meat-tables of tooled stone, as directed, in cellar.

All the walls to have two courses of footings, the upper course to be half a brick thicker than the respective walls, and the lower course half brick thicker than the upper course. The lower course to have binders throughout.

The fire-places to be of width shown on the plans. All the openings to have an arch bar of wrought-iron, three-inch by quarter inch, turned up at each end, and to have an arch turned, with bull-nosed bricks.

A separate flue throughout to be built for each fire-place, fourteen inches by nine, to the height shown, and to be well pargetted throughout, from top to bottom.

The bricklayer to bed and set, with good hair mortar, all bond timber, lintels, and wood bricks. To make good to the balcony bottoms, and all other places requiring the same.

Flush in and back up close behind all stonework.

Make good, and key up to all materials connected with his work, fill in all put-log holes, to point up to all copings and lead flushings, or other projections; to bed and set all corbels, to leave out half a brick for the reception of slopstones, and make good after fixing the same; to cut all skew backs, bevils, chasings for pipes, and otherwise, when required, to make good after the several workmen, when and where required; and to do every thing to complete brick-work in a good workmanlike and substantial manner.

PROCESS FOR SOLDERING IRON AND STEEL.

Melt in an earthen vessel some borax, and one-tenth of sal-ammoniac, and pour out the mixture thoroughly melted on an iron plate; leave it to cool. Add to this vitreous mass an equal quantity of quicklime. The whole being well pulverized, a small quantity is taken which is spread on the piece of iron or steel brought to a red heat. The matter melts and flows like sealing wax. The pieces to be soldered are put back into the fire, but do not require a heat so intense as by the ordinary method of soldering. When withdrawn, they may be hammered at pleasure, and the joining will not be perceptible.—*Echo de la Metallurgie.*

PRINCIPLES OF ALGEBRA.

CHAPTER X.

FRACTIONAL EXPONENTS.

94. By the preceding rule, the quantity $\sqrt[n]{x^m}$ is a simple expression, when m can be divided by n without remainder; but if m be prime to n, that is, if the exponent of the power is not divisible by the index of the root, as in the case of $\sqrt[3]{x^2}$, the extraction to be performed is then algebraically impossible by the rule. But since $\sqrt[n]{x^m} = x^{\frac{m}{n}}$ when m is divisible by n (by the same rule), it has been found convenient to let $x^{\frac{m}{n}}$ *always* stand for $\sqrt[n]{x^m}$. The fundamental condition is equally fulfilled by this notation, since, when $\frac{m}{n} = p$ we have $x^{\frac{m}{n}} = x^p$ and $\sqrt[n]{x^m}$ also $= x^p$. This is exemplified in the following table*.

$\sqrt[2]{x^1}$ or $\sqrt{x}$ is written $x^{\frac{1}{2}}$	$\sqrt[3]{x^2}$ is written $x^{\frac{2}{3}}$
$\sqrt[3]{x}$ . . . $x^{\frac{1}{3}}$	$\sqrt[5]{x^6}$ . . . $x^{\frac{6}{5}}$
$\sqrt[4]{x}$ . . . $x^{\frac{1}{4}}$	$\sqrt[m]{x^n}$ . . . $x^{\frac{n}{m}}$

and so on, observing that the exponent of the power is made the numerator, and the index of the root, the denominator of the fractional exponent of the new notation.

* Expressions of this sort are usually called *surds*, or *irrational quantities*, or *radicals* of the *second*, *third*, or *n*th degree, according to the index of the root required.

95. The rule established for quantities affected with integral exponents are equally applicable when the exponents are fractional. We write in opposite columns instances of the rules: the first column contains those cases which we have proved for whole exponents; and the second, those extensions which we proceed now to establish.

Cases Established.	Cases to be Established.
$x^6 \times x^2 = x^{6+2} = x^8$	$x^{\frac{5}{6}} \times x^{\frac{2}{3}} = x^{\frac{5}{6}+\frac{2}{3}} = x^{\frac{3}{2}}$
$x^6 \div x^2 = x^{6-2} = x^4$	$x^{\frac{5}{6}} \div x^{\frac{2}{3}} = x^{\frac{5}{6}-\frac{2}{3}} = x^{\frac{1}{6}}$
$(x^6)^2 = x^{6\times 2} = x^{12}$	$\left\{x^{\frac{5}{6}}\right\}^{\frac{2}{3}} = x^{\frac{5}{6}\times\frac{2}{3}} = x^{\frac{5}{9}}$
$\sqrt[2]{x^6} = x^{\frac{6}{2}} = x^3$	$\sqrt[3]{x^{\frac{5}{6}}} = x^{\frac{5}{6}\div 3} = x^{\frac{5}{18}}$

The question to be answered is this: are the theorems of the second column true on the supposition, that

$$x^{\frac{m}{n}} \text{ represents } \sqrt[n]{x^m}$$

Case I.—The following will establish the affirmative for multiplication:—

General Process.	Particular Example.
What is $x^{\frac{n}{m}} \times x^{\frac{q}{p}}$?	What is $x^{\frac{5}{4}} \times x^{\frac{2}{3}}$?
$x^{\frac{n}{m}}$ represents $\sqrt[m]{x^n}$	$x^{\frac{5}{4}}$ represents $\sqrt[4]{x^5}$
$x^{\frac{q}{p}}$ represents $\sqrt[p]{x^q}$	$x^{\frac{2}{3}}$ represents $\sqrt[3]{x^2}$
But $\left.\begin{array}{l}\sqrt[m]{x^n} = \sqrt[mp]{x^{np}}\\ \sqrt[p]{x^q} = \sqrt[mp]{x^{mq}}\end{array}\right\}$ by IV.	But $\left.\begin{array}{l}\sqrt[4]{x^5} = \sqrt[12]{x^{15}}\\ \sqrt[3]{x^2} = \sqrt[12]{x^8}\end{array}\right\}$ by VI.
$\therefore\ x^{\frac{n}{m}} \times x^{\frac{q}{p}}$	$\therefore\ x^{\frac{5}{4}} \times x^{\frac{2}{3}}$
$= \sqrt[mp]{x^{np}} \times \sqrt[mp]{x^{mq}}$	$= \sqrt[12]{x^{15}} \times \sqrt[12]{x^8}$
$= \sqrt[mp]{x^{np} \times x^{mq}}$	$= \sqrt[12]{x^{15} \times x^8}$
$= \sqrt[mp]{x^{np+mq}}$	$= \sqrt[12]{x^{15+8}}$ or $\sqrt[12]{x^{23}}$
Which is represented by	Which is represented by
$x^{\frac{np+mq}{mp}} = x^{\frac{n}{m}+\frac{q}{p}}$	$x^{\frac{23}{12}} = x^{\frac{5}{4}+\frac{2}{3}}$
Therefore $x^{\frac{n}{m}} \times x^{\frac{q}{p}} = x^{\frac{n}{m}+\frac{q}{p}}$	Therefore $x^{\frac{5}{4}} \times x^{\frac{2}{3}} = x^{\frac{5}{4}+\frac{2}{3}}$

For exercise. Prove the following instances as above.

$$x^{\frac{1}{2}} \times x^{\frac{2}{3}} = x^{\frac{7}{6}} \qquad x^{\frac{3}{5}} \times x^{\frac{2}{3}} = x^{\frac{19}{15}} \qquad x^{\frac{6}{5}} \times x^{\frac{1}{4}} = x^{\frac{29}{20}}$$

What is $x^{-\frac{n}{m}} \times x^{\frac{q}{p}}$ *Ans.* $x^{-\frac{n}{m}+\frac{q}{p}} = x^{\frac{mq-np}{mp}}$

Similarly: $x^{\frac{n}{m}} \times x^{-\frac{q}{p}} = x^{\frac{n}{m}+(-\frac{q}{p})} = x^{\frac{n}{m}-\frac{q}{p}} = x^{\frac{np-mq}{mp}}$

Case II.—The following answers the question in reference to division.

General Process.	Particular Example.
What is $x^{\frac{n}{m}} \div x^{\frac{q}{p}}$?	What is $x^{\frac{2}{3}} \div x^{\frac{1}{5}}$?
That is $\sqrt[m]{x^n} \div \sqrt[p]{x^q}$	What is $\sqrt{x^2} \div \sqrt[5]{x}$
Or $\sqrt[mp]{x^{np}} \div \sqrt[mp]{x^{mq}}$	Or $\sqrt[15]{x^{10}} \div \sqrt[15]{x^3}$
Or $\sqrt[mp]{x^{np} \div x^{mq}}$	Or $\sqrt[15]{x^{10} \div x^3}$
Or $\sqrt[mp]{x^{np-mq}} = x^{\frac{np-mq}{mp}}$	Or $\sqrt[15]{x^{10-3}} = x^{\frac{7}{15}}$
But $\frac{np-mq}{mp} = \frac{n}{m} - \frac{q}{p}$	But $\frac{7}{15} = \frac{2}{3} - \frac{1}{5}$
Therefore $x^{\frac{n}{m}} \div x^{\frac{q}{p}} = x^{\frac{n}{m}-\frac{q}{p}}$	Therefore $x^{\frac{2}{3}} \div x^{\frac{1}{5}} = x^{\frac{2}{3}-\frac{1}{5}}$

For Exercise. In the same way prove the following instances:

$$x^{\frac{2}{3}} \div x^{\frac{1}{3}} = x^{\frac{1}{3}} \qquad x^{\frac{3}{2}} \div x^{\frac{1}{4}} = x^{\frac{5}{4}} \qquad x^{\frac{2}{5}} \div x^{\frac{2}{9}} = x^{\frac{8}{45}}$$

$$\frac{x^{\frac{3}{2}}}{x^{\frac{1}{5}}} = x^{\frac{13}{10}} \qquad \frac{\sqrt[3]{x^2}}{x^{\frac{1}{4}}} = x^{\frac{5}{12}} \qquad \frac{x^{\frac{6}{5}}}{\sqrt{x^3}} = \sqrt[10]{x^{-3}}$$

What is $x^{\frac{n}{m}} \div x^{-\frac{q}{p}}$? *Ans.* $x^{-\frac{n}{m}-(-\frac{q}{p})} = x^{\frac{mq-np}{mp}}$

Similarly, $x^{-\frac{n}{m}} \div x^{\frac{q}{p}} = x^{-\frac{n}{m}-\frac{q}{p}} = x^{-\frac{np+m}{mp}}$

Also $x^{\frac{2}{3}} \div x^{-\frac{3}{4}} = x^{\frac{17}{12}}$ $\qquad \sqrt{x^{-1}} \div \sqrt[3]{x^{-4}} = x^{\frac{5}{6}}$

$$\frac{\sqrt{x^{-3}}}{x^{-\frac{1}{4}}} = x^{-\frac{5}{4}} \qquad \frac{\sqrt[4]{x^3}}{\sqrt[3]{x^{-2}}} = x^{\frac{17}{12}} \qquad \frac{x^{-\frac{1}{2}}}{\sqrt[3]{x^{-2}}} = \sqrt[6]{x}$$

Case III.

General Process.	Particular Example.
What is $\left\{x^{\frac{n}{m}}\right\}^{\frac{q}{p}}$?	What is $(x^{\frac{2}{3}})^{\frac{4}{5}}$?
This means $\sqrt[p]{\left\{\sqrt[m]{x^n}\right\}^q}$ by definit.	This means $\sqrt[5]{\left\{\sqrt[3]{x^2}\right\}^4}$
Or $\sqrt[p]{\sqrt[m]{(x^n)^q}}$ by art. III.	Or $\sqrt[5]{\sqrt[3]{(x^2)^4}}$
Or $\sqrt[mp]{x^{nq}} = x^{\frac{nq}{mq}}$	Or $\sqrt[15]{x^8} = x^{\frac{8}{15}}$
But $\frac{nq}{mp} = \frac{n}{m} \times \frac{q}{q}$	But $\frac{8}{16} = \frac{2}{3} \times \frac{4}{5}$
Therefore $\left\{x^{\frac{n}{m}}\right\}^{\frac{q}{p}} = x^{\frac{n}{m} + \frac{q}{p}}$	Therefore $(x^{\frac{2}{3}})^{\frac{4}{5}} = x^{\frac{2}{3} + \frac{4}{5}}$

Verify $(x^{\frac{1}{2}})^{\frac{2}{3}} = x^{\frac{1}{3}}$ $\qquad (y^{\frac{1}{2}})^m = \sqrt{y^m}$

What is $(x^{-\frac{n}{m}})^{-\frac{q}{p}}$ Ans., $x^{-\frac{n}{m} \times (-\frac{q}{p})} = x^{\frac{nq}{mp}}$

for $(x^{-\frac{n}{m}})^{-\frac{q}{p}}$ means $\sqrt[p]{(\sqrt[n]{x^{-n}})^{-q}}$

Also, $(x^{-\frac{n}{m}})^{\frac{p}{q}} = x^{-\frac{nq}{mp}}$

The preceding case contains both the third and fourth conditions of the question in Art 95; for it is manifest that the discussion of

$$(x^{\frac{n}{m}}) = \sqrt[p]{x^{\frac{n}{m}}} \text{ is also the discussion of } \sqrt[p]{x^{\frac{n}{m}}} = (x^{\frac{n}{m}})^{\frac{1}{p}}$$

96. *On the signs of Powers.*—What are the mth powers of $\pm x$? By definition,

$$(\pm x)^m = (\pm x)(\pm x)(\pm x)(\ \ldots \text{ to } m \text{ factors.}$$

Now, the product of any number of positive terms being positive,

$$\therefore (+x)^m = +x^m \text{ when } m \text{ is any number;}$$

that is, *every power of a positive quantity is a positive quantity.*

And as every pair of negative factors gives a positive product; and as even numbers are made up of one or more pairs.

$$\therefore (-x)^m = +x^m, \text{ when } m \text{ is any } even \text{ number;}$$

that is, *every even power of a negative quantity is a positive quantity.*

And, lastly, as every positive quantity multiplied by a negative factor, gives a negative result, and as every odd number greater than 1 is an even number increased by 1,

$$\therefore (-x)^m = -x^m, \text{ when } m \text{ is an odd number;}$$

that is, *every odd power of a negative quantity is a negative quantity.*

These two last theorems may be more generally expressed thus: $2n$ being always an *even* number when n is any integral number whatever, and $2n+1$ always an *odd* number; therefore

$$(-x)^{2n} \text{ always } = +x^{2n}$$
$$(-x)^{2n+1} \text{ ,, } = -x^{2n+1}$$

Thus $(-x)^4 = (-x)(-x)(-x)(-x) = (+x^2)(+x^2)$
$= +x^4$

$(-x)^5 = (+x^4)(-x) = (+x^5)(-1) = -x^5$

$(-x^2)^2 = (-x^2)(-x^2) = +x^4$

$(-x^2)^3 = -x^6$

97. Since $-x = x(-1)$, and $-x^m = x^m(-1)$; and in like manner

$$(-x)^m = x^m(-1)^m$$

which is positive or negative, according as m is an even or odd number.

The expression $(-x)^m$ must not however be confounded with $-x^m$, which is necessarily $= x^m(-1)^m$

98. *On the Signs of Roots.*—Since, in as far as the result is concerned,

$$(\pm x)^{2n} = (+x^n)(+x^n) = (-x^n)(-x^n) = +x^{2n}$$

and $\sqrt{+x^{2n}} = (+\sqrt{x^n})(+\sqrt{x^n})$
$= (-\sqrt{x^n})(-\sqrt{x^n}) = +\sqrt{x^{2n}}$

it follows that the $2n$th or *even* root of a quantity may have either the positive or negative sign prefixed. For instance,

$\sqrt{a^2} = +a$ or $-a$, since $(+a)^2 = a$ and $(-a)^2 = a^2$

Similarly: $\sqrt{a^3} = +a^{\frac{3}{2}}$ or $-a^{\frac{3}{2}}$, for $(\pm a^{\frac{3}{2}})^2 = a$

Again, $(+x)^{2n+1} = (+x^n)(+x^n)(+x)$
$= (-x^n)(-x^n)(+x) = +x^{n+1}$

$(-x)^{2n+1} = (-x^n)(-x^n)(-x)$
$= (+x^n)(+x^n)(-x) = -x^{2n+1}$

Hence it follows that the $(2n+1)$th or *odd* root of any quantity has the same sign as the quantity itself. For instance,

$\sqrt[3]{+a^3} = +a$, but not $-a$; for $(+a)^3$ only $= +a^3$

$\sqrt[3]{-a^3} = -a$, but not $+a$; for $(-a)^3$ only $= -a^3$

99. *Of Imaginary Quantities.*—What is the square root of $-x^2$ The required root is manifestly neither $+x$ nor $-x$, since neither $(+x)(+x)$ nor $(-x)(-x)$ gives $-x^2$

But $-x^2 = x^2(-1)$; therefore $\sqrt{-x^2} = \sqrt{x^2(-1)}$

and this last $= \sqrt{x^2}\sqrt{-1}$, which is $\pm x\sqrt{-1}$

Also $\sqrt[4]{-x^4} = \pm x\sqrt{\sqrt{-1}}$ $\qquad \sqrt[6]{-x^6} = \pm x\sqrt[3]{\sqrt{-1}}$

and generally $\sqrt[2n]{-a^{2n}} = \sqrt[2n]{a^{2n}(-1)} = \pm x\sqrt[n]{\sqrt{-1}}$

from which it appears that every *even* root of a negative quantity is reducible to the determination of $\sqrt{-1}$. But since the value of $\sqrt{-1}$ cannot be assigned arithmetically, either accurately or approximately, quantities in which it occurs as a factor are said to be *imaginary* or *impossible.* All arithmetical operations upon such quantities therefore depend upon the treatment of $\sqrt{-1}$, and present no difficulty when it is observed that

$\sqrt{-1} \times \sqrt{-1} = (\sqrt{-1}) = -1$

$(\sqrt{-1})^2 \times \sqrt{-1} = (\sqrt{-1})^3 = -1 \times \sqrt{-1} = -\sqrt{-1}$

$(\sqrt{-1})^3 \times \sqrt{-1} = (\sqrt{-1}) = -\sqrt{-1} \times \sqrt{-1}$
$= -(\sqrt{-1})^2 = -(-1) = +1$

$(\sqrt{-1}) \times \sqrt{-1} = (\sqrt{-1})^5 = +1 \times \sqrt{-1} = \sqrt{-1}$

and so on, all succeeding powers being the product of one or other of these four by $+1$. The recurring powers are therefore as follows:—

1st, 5th, 9th, 13th, &c. $= \sqrt{-1}$
2nd, 6th, 10th. 14th, &c. $= -1$
3rd, 7th, 11th, 15th, &c. $= -\sqrt{-1}$
4th, 8th, 12th, 16th, &c. $= +1$.

Retaining these views we readily obtain

$$\sqrt{-a}\sqrt{-b} = \sqrt{a}\sqrt{b}(\sqrt{-1})^2 = -\sqrt{ab}$$
$$\sqrt[4]{-a}\sqrt[4]{-b} = \sqrt[4]{ab}(\sqrt[4]{-1})^2 = +\sqrt[4]{ab}\sqrt{-1}$$
$$\frac{\sqrt{-a}}{\sqrt{-b}} = \frac{\sqrt{a}\sqrt{-1}}{\sqrt{b}\sqrt{-1}} = \sqrt{\frac{a}{b}} \qquad \frac{\sqrt{-a}}{\sqrt{b}} = \frac{a}{b}\sqrt{-1}$$
$$(\sqrt[2n]{-a})(\sqrt[2n]{-b}) = \sqrt[n]{ab}\sqrt[n]{\sqrt{-1}}$$

These operations frequently occur in the management of operations, and ought therefore to be studied with care, as the misinterpretation of a sign will often lead to a very erroneous result.

A quantity such as $\sqrt{2}$ is called an irrational number, or a surd, because no number, either whole or fractional, can be found, which, when multiplied by itself, will produce 2. But its approximate value may be determined to any degree of exactness.

BOOKS AND LIBRARIES.

THERE is possibly no greater and no more absolute waste of precious time than in reading, and yet, seemingly contradictory as it may appear, there are few purposes to which the leisure hours of life can be devoted with more present enjoyment and more ulterior advantage to the individual. This is true in theory, fact, and experience. To read for the mere sake of reading—to run the eye over the pages of a book, with no present or ulterior purpose, and for no better object than the gratification of an empty desire to accomplish the task, can afford little more satisfaction to the individual than the contemplation of having at some former period of life indulged in the luxury of blowing a penny whistle. We do not in this express a prejudice against what is usually denominated *light reading*, if by that name we are to understand reading which affords enjoyment by well contrived and lively exhibitions of life and manners in the various grades of society, past and present. Our fashionable novels, it is true, are often about as destitute of instruction in the practical morality which it is the business of such writings to unfold and illustrate, as is music of momentum. But even the cobweb novel, manufactured like the rogue's razors, *to sell*, may, like music, afford its momentary enjoyment; and, though transient and illusory, it is positive while it lasts: and may serve to beguile the mind into a happier train of reflection, and give to the stern realities of life a less gloomy aspect. And if this much be effected—if a harmless enjoyment be obtained, and if enjoyment be the purpose of life and the reward of living, the hours expended in the indulgence of it cannot be regarded as negative units in summing up the elements of life.

All this and more is true; yet, while we do not join in the puritanical denunciation of novel reading as a sinful waste of time, still we adhere to the doctrine, that much of our reading is a barren expenditure of that most valuable portion of life—that portion of it which consists of relaxation from the task of providing by our labour for the demands made upon us by the necessities of our nature, the customs and institutions of society, and the gratification of those tastes and appetites which belong to civilized man, and among which *reading* holds a distinct and characteristic position. More explicitly—it is not the species of reading which we would pronounce to be fruitless exercise of the organs of vision, but the manner of it. The man who read Euclid on an evening after tea put himself to a great deal of unnecessary trouble; he passed his hours far less profitably than if he had indulged himself in a stale laugh with Joe Miller, or with more gravity had scanned the features of the crooked family, or criticised the architecture of the famous house that Jack built. As in any other occupation for the time, that a result may be attained there must be an object in view—a something to be gained in the form either of present enjoyment or of future advantage; but to read a volume which affords neither instruction nor enjoyment, is manifestly the lowest species of trifling: in fact, hardly moral, in so far as a self-deception is practised, for which there is no excuse. The fault may be neither with the book nor with the individual: the one may be well written, contain much valuable material of its kind, and the other may have a due share of intelligence and aptitude for enjoyment, but they may not suit each other; their temperaments may be opposite and out of sorts when together. It is true time may be beguiled—*killed*, as the fact is emphatically expressed, under certain circumstances, by the perusal of a page, which to the individual seems to contain only a collection of words rounded off into periods, which flow with tolerable smoothness; and if the circumstances be irksome, and the formulary of words act as a soporific, an object has been served. But the inquiry returns, whether a more desirable effect could not have been produced in the same time and by a more agreeable application of the mind to a subject in which it might find an interest; and moreover, there are few rules to which there are not some special exceptions; and the exception founded on occasional circumstances which may induce an individual to seek an opiate of printers' ink, is not sufficient to invalidate the position, that "reading for reading's sake" is a fallacy which ought to have no countenance, at least among those whose hours for instruction, recreation, and enjoyment, are limited by the labour and repose which necessarily claim the largest portion of the existence of the mass of society.

The object to be attained by reading is amusement or instruction, and both together if possible. The present is a reading age, and books are now reckoned as necessary to an intelligent man as the food by which the healthy action of his muscular system is maintained. Through the medium of the press his intelligence is brought into contact with the superior minds of all ages and of all countries; and whatever be his tastes, pursuits, and cravings of the mind, the library is provided with the requisite materials to supply his peculiar demands. From the press society receives its tone: every species of improvement, instruction, information, and intellectual enjoyment pass through it; and as education extends its influence will augment and wax more potent in providing for the increasing claims made upon its unwearied industry.

The multiplicity of books, and other minor products of the press, has however its embarrassing effects, and especially so to the working man, whose leisure and means are slender. Selection is to him of the utmost importance; and even to the constant *litterateur*, with leisure and means in abundance, this is not only a great labour, but a nice art, and one which can be efficiently practised only by those in the most advantageous circumstances for discrimination. That any individual, however favourably circumstanced, can read more than a selection of the books that issue from the press, is manifestly impossible; and how far and emphatically this applies to the working man we leave him to consider. As selection is, therefore, absolutely necessary, and necessary in proportion as the time and means of the individual are limited, and consequently the more valuable, there can hardly be a greater benefit conferred upon a reading community than arises from the periodical publication of critical notices of the products of the press as they issue from it. Much is done in this way by the periodical portion of the press; but still much is left undone, and possibly it might not be practicable to concentrate the whole into one focus.

But, besides selection, economy of means is also requisite on the part of the working man; and both purposes are in some measure effected by the institution of libraries and book-clubs, when well conducted. If it be impossible for an individual to keep pace with the press in reading, it can hardly be expected that he will keep pace in purchasing; and in the case of the operative the purchase of a single book is to him a matter of consideration. The difficulty, however, is removed when he becomes a member of a good library: he is then placed on a footing of equality with the most opulent, for he has a command of more than he can make use of; and the library is not well managed if the materials contained in it are not of the best description; in fact, a judicious selection from every department of the published literature of moral and physical science, the arts, practical and industrial, history, fiction, and poetry. In this there is to him an economy both of time and of means—the range of his selection is brought within a moderate compass—to him the library is the world of literature, beyond which he regards not the outpouring of the press and its attempts to call attention to its doings.

But whilst the readers generally are exempted from the direct task of selecting their reading from the wide world of literature, and have it brought within a narrow compass, this duty must devolve upon the persons having the control of the affairs of the library; and where the library is the property of the subscribers, this duty must either be undertaken by them—that is, by a committee of their body, or by a person in whose knowledge and judgment they have confidence. This is often the preferable mode; but as every man believes himself the best judge of his own wants and wishes, and, moreover, is unfond of relinquishing any means by which his happiness may be promoted, it is rarely practised in that species of minor libraries which we have at present mainly in view. Of this kind are the libraries belonging to Mechanics' Institutions.

and which indeed form part and parcel of these establishments, and those cheap book-clubs, such as that of Mauchline which the poet Burns, when young in manhood and unknown to fame, was chiefly instrumental in establishing. The history of this first attempt of a few rustics to provide mental aliment for themselves is recorded by Dr. Currie in his history of the ploughman bard, and is not without interest and useful example at the present day. The poet's own account of the rise and progress of his first club at Tarbolton, which preceded that of Mauchline, is characteristic, and has its value in as far as it enforces a doctrine which has been much overlooked by the theorizers on the social improvement of the working classes. The following is the preamble:—

"Of birth or blood we do not boast,
Nor gentry does our club afford;
But ploughmen and mechanics we
In Nature's simple dress record."

"As the great end of human society is to become wiser and better, this ought therefore to be the principal view of every man in every station of life. But as experience has taught us that such studies as inform the head and mend the heart, when long continued, are apt to exhaust the faculties of the mind, it has been found proper to relieve and unbend the mind by some employment or another, that may be agreeable enough to keep its powers in exercise, but at the same time not so serious as to exhaust them. But superadded to this, by far the greater part of mankind are under the necessity of earning the sustenance of human life by the labour of their bodies, whereby not only the faculties of the mind, but the nerves and sinews of the body are so fatigued, that it is absolutely necessary to have recourse to some amusement or diversion to relieve the wearied man worn down with the necessary labours of life.

"As the best of things, however, have been perverted to the worst of purposes, so, under the pretence of amusement and diversion, men have plunged into all the madness of riot and dissipation; and instead of attending to the general design of human life, they have begun with extravagance and folly, and ended with guilt and wretchedness."

This was, however, a club without books; it met mostly for the purposes of conversation and discussion, and the fines levied upon the members were spent in conviviality. But, profiting by experience, and a change of residence to Mauchline, the future poet succeeded in establishing a similar club in that locality, with one important alteration: the fines were set apart for the purchase of books, and the first volume of the library was "The Mirror." Dr. Currie, in recording this fact, remarks—"With deference to the conversation society of Mauchline, it may be doubted whether the books which they purchased were of a kind best adapted to promote the interest and happiness of persons in their situation of life." This objection was no doubt dictated by the opinion that works which tend to cultivate delicacy of taste, are unfit for those who pursue manual occupations—an opinion which has a wide and deep hold of the public mind, notwithstanding the efforts which have been made by the friends of the operative to eradicate it. Caricature upon caricature have expressed the same sentiment in reference to the efforts of the societies for the diffusion of useful knowledge, and when the contrary is expressed it is usually in so hesitating a manner as to make it be suspected that theory and practice ought not to be reconciled in this as in physical science. Dr. Currie, however, qualifies his objections by the observation, "that every man is the best judge of his own happiness, and within the path of innocence ought to be permitted to pursue it. Since it is the taste of the Scottish peasantry to give a preference to works of taste and fancy, it may be presumed they find a superior gratification in the perusal of such works." This truth ought undoubtedly to be the criterion by which the books in every select library should be chosen: it ought to guide every attempt to render the selection useful to the greatest possible extent. In respect to the higher class of works of literature, there is no room for error; a knowledge of them speedily descends through all ranks of society; they are addressed to the universal mind, and find a response more or less distinct in every individual unit of it. It is in those works of an exclusive caste that selection is more especially required—in which it is of more difficult experience. We cordially acquiesce in the sentiments of an article on this subject in one of the recent periodicals, in which it is observed that "those works which aim at exclusiveness are the perishable productions which have their little day of drawing-room fame, and can never reach the greatest of all honour, that of making the labourer forget his toil in his free and equal converse with minds that shed their radiance indifferently on the cottage and on the palace. We are learning (slowly) to correct the false opinions which for a century or two have been degrading the national character and lowering the general taste. Those who maintained that taste was the exclusive property of the rich and the luxurious, could not take away from the humble the beauty of the rose or the fragrance of the violet; they could not make the nightingale sing a vulgar note to the 'swink'd hedger at his supper;' nor, speaking purely to a question of taste, did they venture to lower the translation of the Bible, which they put into the hands of the poor man, to something which, according to the insolent formula of those days, was 'adapted to the meanest capacity.' A great deal of this has passed away. It has been discovered that music is a fitting thing to be cultivated by the people; the doors of the galleries are thrown open to the people to gaze upon Raffaelles and Corregios; even cottages are built so as to satisfy a feeling of proportion, and to make their inmates aspire to something like decoration. All this is progress in the right direction"—rather it is a preparation for progress, an indication, like the troubling of the pool, that a healing spirit has descended.

In the selection of books which an individual ought to peruse, rather which he may read, while there is much room for diversity of opinion, taste, and judgment, there is also much scope for the exercise of an extended knowledge and acquaintance with the wants of those for whom the selection is made. While we do not subscribe to the doctrine that all reading is worthless which does not "inform the judgment or mend the heart"—if by this we are to understand direct addresses to either—we cannot at the same time fully subscribe to Dr. Johnson's suggestion, to turn a boy loose into a library, having previously removed all works of an injurious tendency, and let him graze as he likes, unless indeed the library be a well selected one; still we cordially acquiesce in the concluding remark "that nothing can be worse than to enclose him in one small field of knowledge with thorn hedges, a cord and a staple. The confines of the pasture would speedily destroy its relish. Instead of binding down his eye and attention to a single book, let him please his appetite in selecting in accordance with his own taste; and above all, abstain from discouraging him with a statement of difficulties beyond the reach of his understanding. If he find the trunk of the tree too huge and knotty for his arms to encircle it, he will of his own accord soon abandon the attempt to climb to the boughs."

The only objection to the great Doctor's argument is, the difficulty which the boy will find in knowing beforehand what works will mostly interest him, to what subjects he can with best advantage direct his attention in the limited time which is permitted to pasture in this luxuriant field.

Another hypothesis, of which the same astute moralist was the author, is that no man ever reads a work of science from pure inclination. He follows up this doctrine by the assertion that the only books really perused with pleasure are merely those which contain a quick succession of events. In venturing upon this remark he had probably in his recollection the day when he read through Fielding's *Amelia* without stopping; but the assertion is far from being generally true; and had Johnson known as much of physical as he did of moral science, he would have been among the first to controvert such an opinion had he heard it expressed. The Doctor, however, had little knowledge of—consequently little taste for physics, and therefore expressed only his own experience. But had that experience extended to the *Principia*

of Newton, he might have found that the progress which the understanding makes through a book has *not* in it more pain than pleasure. The mind embued with science can and does pursue it as essentially for the pleasure it affords, as did the colossal doctor pore over the incidents in the story of *Amelia*. But while this is true, it is also to be admitted that the taste for incident belongs to every mind, whilst that for science is confined to a few. None but the most incorrigible dolt can fail to appreciate the adventures of *Ivanhoe*, while it requires much previous training and some mental aptitude to derive enjoyment from the refinements of the differential calculus. The difficulty, however, consists not in the abstractness of the subject, but in awakening a taste for the inquiries which it necessarily implies; and no matter whether the subject be a narrative or a mathematical process.

To suit the general mind, and provide for its expansion, the library ought thus to be furnished, not with a single class of books, but with a selection of the best works embracing the round of literature, science, and the arts. A library of this character is particularly important to the Mechanics' Institute. Such a library to be—as it ought—the standing and staple tower of support, the constant and abiding fund of interest and attraction when other means are suspended or impracticable, ought obviously to contain books of a kind to create in the first place a desire for reading—books which amuse without depraving the mind—always presuming the due, rather the full proportion of books of science and useful knowledge, to be provided for the readers of a more advanced class.

On this subject the writer in the *Westminster Review*, formerly quoted, observes—" The Waverley Novels ought to be the first and foremost in the catalogue of every Mechanics' Institution library. We know personally a man of some eminence at the present moment who ascribes his acquisition of a desire for knowledge to the perusal of these novels, obtained by him when a lad from the library of a Mechanics' Institution. To the fictions of Scott should be added the works of Edgeworth, Cooper, Dickens, and of many other authors whose names will occur to every one acquainted with the ordinary history of letters. Let no one take fright at the idea of novel reading at a time when the strength with which the best and purest current of thought amongst us runs in the channel of fiction, is one of the most remarkable features in the intellectual condition of the age. There should also be a plentiful sprinkling of voyages and travels, and biography."

The correctness of these remarks have been found by experience in most mechanics' libraries; the higher classes of novels, such as those cited, magazines, narratives, books of travels, being uniformly the most read and best thumbed volumes in the collection, and hence requiring frequent renewal, while the scientific portion remains for a long time in a state of high preservation.

With respect to book-clubs, or reading societies, several of these exist among the more opulent, but few for the operative. In the larger towns they are less required, as the libraries of the Mechanics' Institutions, the numerous private libraries which exist, in some measure supply the demand without the usual cumbrous machinery with which the reading society is clogged, and it must be added, needlessly clogged in its operations. This difficulty, indeed, seems to be one potent reason why those societies have not hitherto been attended with that success which they deserve, and in villages and country districts where Mechanics' Institutions could not be established with much prospect of usefulness, we know of no better and cheaper mode of providing for the wants of the reading portion of the community: a portion, it must be admitted, not very numerous in such localities. The plan was fully developed by Lord Brougham twenty years ago in his " Practical Observations upon the Education of the People." It has neither, however, been attempted nor successful to any marked extent; and where it has led to failure, the defect may commonly be traced to the multiplicity of regulations by which the working of the association has been burthened.

We have referred to the difficulty which those little acquainted with the history of letters have in selecting their own reading; and if left entirely to their own guidance, they are apt—indeed compelled to read without choice or aim. This might be easily remedied in preparing the catalogue of the library. Instead of the dry list of names which commonly compose the catalogue, a note stating the kind and character of the book might be appended to each. This would be attended with the disadvantage of somewhat swelling the catalogue; but in our opinion it would save to the readers, and also to the librarian, much valuable time. Outlines also of a course of reading in the various departments of literature and useful knowledge might with great advantage be appended. Especially in the arts, no volume would be more useful than a library volume carefully prepared, of the books which treat of particular departments, and for which Dr. Thomas Young's catalogue furnishes a perfect model.

THE PHENOMENA OF EVAPORATION, FORMATION, AND SUSPENSION OF CLOUDS.

By G. A. Rowell, Esq.

The phenomena of evaporation, the formation and suspension of clouds, &c., are so varied, that it is generally allowed that no theory hitherto proposed will explain the subject satisfactorily, and it is difficult to find authors agreeing to the same explanation. The theory adopted by the writer on this subject in the Encyclopedia Britannica (that water is taken up in solution in the air), is generally given up; for although it explains evaporation in air very well, it does not explain the cause of evaporation in vacuo, or account for the formation and suspension of clouds, or how clouds obtain their electricity.

The theory proposed by the late eminent philosoper, Dr Dalton, that evaporation is caused by the absorption of caloric by water, is adopted by Mr Howard and other leading meteorologists, but this theory also fails in a similar way; one objection is, that ice and snow will evaporate when surrounded by air below the freezing temperature; now, as ice is water deprived of its 140 degrees of heat of fluidity, from what source can it derive its caloric to convert it into vapour, when surrounded by a freezing atmosphere?

Again, the great heights at which clouds are sometimes seen, tell against the theory, as the following will show the enormous expansion of vapour necessary to render it buoyant, and, at the same time, the great reduction of temperature at such heights.

Heights.	Temperature of Air.	Density of Air.	Expansion of Water to Float.
Level of the sea,.........	+ 60°	1·	860
1 Mile,......................	+ 43°	0·7943	1083
2 Miles, ...	+ 26°	0·6309	1363
3 Miles, ...	+ 9°	0·5011	1716
4 Miles, ...	— 8°	0·3981	2160
5 Miles, ...	— 25°	0·3163	2719
Expansion of steam at 212° is 1800 times.			

Five miles is far above the usual height of clouds, but we have undoubted authority that clouds are sometimes seen at that height. But even at three miles high, the expansion of vapour to float must be 1716 times (very near the expansion of steam from boiling water), and the temperature reduced to 23° below the freezing point. This, I believe, will be sufficient proof that the ascent and suspension of vapour, at such heights, must be caused by some agent, which is uninfluenced by heat or cold.

The hypothesis I offer on this subject is, that when expanded by heat, the increase of the surface of particles of water giving them a greater capacity for electricity, they are buoyed up into the air by their coating of electricity; that if condensed near the earth's surface, the extra quantity of electricity is withdrawn, and the vapour falls as dew, &c.; but if it rises out of the electrical attraction of the earth, and is then condensed, the electricity being insulated, forms an atmosphere around each particle of vapour, which surcharge of electricity not only suspends the vapour by its lightness, but also repels the neighbouring particles of vapour, and prevents the formation of rain; and on the removal (by any cause) of

the electricity inclosing the vaporous particles, the repulsion* is removed, and the particles attract each other, and form rain.

Before I endeavour to explain the various phenomena in question, by this hypothesis, I would direct attention to some of the acknowledged properties of electricity, namely: it has no weight, occupies no space, and is dependent on the surface rather than the bulk of bodies; and also to the rapid increase of the surface of bodies, *in proportion to their bulk*, as their bulk diminishes; thus, adopting the $\frac{1}{5000}$ part of an inch as the diameter of a particle of vapour, and the $\frac{1}{25}$ part of an inch as the diameter of a drop of rain, it would take 8,000,000 particles of vapour to form a drop of rain; but the surface of the rain drop would only equal that of 40,000 particles of vapour, therefore, the surface and consequent capacity of each particle of the vapour for electricity, is 200 times greater than that of the rain-drop, bulk for bulk; and as we have no means of judging what is the real diameter of a particle of water, it is probable that it is much smaller than the diameter I have adopted, and, therefore, has a much greater capacity for electricity, proportionate to its bulk.

Thus it will be seen, that if electricity coats the surface of bodies, there must be some point at which the surface of a body would be so great in proportion to its bulk, that this coating of imponderable matter would render it buoyant.

I will now endeavour, as briefly as possible, to explain the phenomena by this hypothesis.

As heat expands the particles of water, it increases their capacity for electricity: therefore, all other circumstances being alike, the greater the heat the greater the evaporation.

Evaporation must depend on the surface exposed, and not on the volume of water, as only the particles on the surface of the water can obtain their coating of electricity.

Wind increases evaporation by assisting the particles of vapour to separate from the body of water, thus enabling the particles to obtain their full coating of electricity, which they cannot have while resting on the surface of the water.

Evaporation from ice is owing to the coldness and dryness of the air separating the minute particles of the surface; when, obtaining their coating of electricity, they are rendered sufficiently buoyant to be carried off by a brisk wind.

Evaporation from ice, snow, or even water, at very low temperatures, is trifling except during windy weather.

Evaporation in vacuo (*i. e.* under an exhausted receiver) arises from the weight of the atmosphere being taken off, when the particles of water are buoyed up one upon another by their electrical coatings.†

Vapour, when raised, if condensed near the earth, is then surcharged by the contraction of its surface, and, being attracted to the condensing substance, forms dew; or, if the surcharge escapes to the earth, the vapour is rendered scarcely buoyant, and causes fogs, &c.

When vapour rises to a distance from the earth, and is then condensed, the surcharge of electricity still buoys it up, and, forming an electrical atmosphere round each particle, prevents the formation of clouds or rain until this surcharge escapes; and the more the vapour is expanded on its first rising, the greater will be its charge of electricity, and it will rise to a corresponding height.

The vapour in the region of the clouds is generally, or at all times, condensed, but invisible, from its being so diffused; the breath of animals is condensed and visible, in cold weather, close to the mouth, but invisible at a short distance off, where it is more condensed, but more diffused; and the deep blue of the sky at great elevations, as described by Saussure, Humboldt, and others, makes it probable that the light colour of the sky at lower latitudes is owing to the condensed vapour floating in the air.

The formation of clouds is, in general, not owing to the sudden condensation of the vapour, but to the escape of its electricity, thus allowing the particles to be brought nearer by the attraction of aggregation; and a still further escape of the electricity enables such attraction to overcome the electrical repulsion of the particles, and to form rain.

Mountains and high hills cause rain, by conducting the electricity from the clouds and vapour, and not as condensers of vapour.

Rain is also caused by the air between the earth and clouds becoming charged with vapour, and thus conducting the electricity from the vapour above.

Extensive fires, volcanoes, &c., cause rain from the smoke and vapour bringing the air into a conducting state.

Pressure is another cause of rain; thus, if a cloud be forming, the accumulation of vapour is from every side, but chiefly above, and clouds are, at times, of great depth; now, every particle of vapour, on joining the cloud, would have its extra charge of electricity over the particles of the cloud instantly dispersed through the whole mass, and would take its level in the atmosphere according to its density; but, as all the particles in the cloud are of the same density, those particles of vapour which are above the mean line of density would press downwards, and those below that line would react on those above; and although the electrical repulsion of the particles be sufficient to prevent rain at the edges and thinnest part of the cloud, the pressure at the greatest depths of the cloud may be sufficient to overcome the repulsion, and form rain.

The concussion caused by a flash of lightning from such a cloud (that is, with its particles pressed nearly into contact) will easily explain the cause of the heavy dash of rain which follows the flash of lightning.

Rain caused by pressure will often take place at much greater elevations than that caused simply by the gradual escape of the electricity of the vapour, which will account for the formation of hail: thus, a cloud is wafted from a warm to a colder region, and although the cold may be sufficient to freeze all the particles of vapour at the exterior of the cloud, the radiation of heat would be prevented from the central part, where the vapour would remain unfrozen. Rain, formed in the middle of such a mass of vapour, would increase in size in falling through the lower part of the cloud; it would be instantly frozen on leaving the cloud, and the drop, formed under such circumstances, being large, would not only remain frozen in falling through the warmer strata of air to the earth, but would also increase in size by attracting to itself other vapour; but the rain or snow falling from the thinner parts of the cloud being in smaller drops, if frozen in the higher regions, would be melted in falling through the warmer air; thus, as is often the case, there is heavy hail and rain falling at the same time from the same cloud.

The successive flashes of lightning from the same cloud may be caused by the electricity being pressed out of the cloud when the electric fluid accumulated on the surface would strike off either to the earth or neighbouring clouds; or it may be caused by the formation of rain; thus, it takes 8,000,000 particles of vapour to form one drop of rain, but the capacity for electricity of the rain-drop is only equal to that of 40,000 particles of vapour; therefore, on the formation of every drop of rain, the electricity of 7,960,000 particles of vapour must be dispersed through the remaining vapour, and thus increase the electrical charge of the cloud.

The same reasoning will account for the dispersion of clouds after rain; for if the electricity does not, by some means, escape from the cloud in so great a proportion as the accumulation goes on through the formation of rain, the electricity must increase so as to stop the formation of rain; and may disperse the cloud altogether, through the increased repulsion of the particles of vapour.

The sinking in the barometer previous to and during rain, I ascribe to the rapid escape of electricity from the invisible vapour

* In using the term repulsion, I mean that the particles repel each other to the extent of their electrical coating, *and no farther:* that bodies similarly electrified (either positively or negatively) recede from each other to considerable distances may, I believe, be attributed to the influence of surrounding objects; thus, if a globe be charged, it will attract and be attracted in all directions; now, if the globe be so fragile, as that this attraction is sufficient to separate it into minute fragments, these, having no attraction for each other, would be attracted apart by surrounding objects, and not dispersed through any repulsion amongst themselves. My views may be wrong, but I cannot otherwise account for the collection of particles of vapour into clouds, especially when highly charged, as in thunder-storms.

† The following extracts from the *Philosophical Magazine*, January 1842, will show the agency of electricity in evaporation:—

"The following experiment was made to prove that evaporation would not go on so freely from an insulated vessel as from an uninsulated one:—

"In a warm room, over an oven in daily use, I suspended, by silk threads, two shallow vessels, eight inches and a half in diameter, containing eight ounces of water each; a small copper wire was hung from one vessel to the earth to take off the insulation, both vessels being similarly suspended in every other respect. After being suspended 25 hours, the insulated vessel had lost 2 oz. 11 dwts. and 15 grains; and the other vessel, 3 oz. 6 dwts.; showing an excess of evaporation from the non-insulated one of 14 dwts. 9 grains.

"I have tried similar experiments with water placed in the rays of the sun, and, on all occasions, the evaporation has been greatest from non-insulated vessels. There is a difficulty in obtaining correct calculations from the above experiments, as it is scarcely possible to keep up complete insulation from electricity; and the vessel of water must have its proportion of electricity when placed in an insulating situation, which will assist the evaporation for sometime; but I believe, if complete insulation could be obtained, and a vessel left without any electricity, that no evaporation would go on at moderate temperatures."

It has long been well known that evaporation is increased by water being charged with electricity; this increase was attributed to the particles of water being repelled from the surface, as any light substance is from a charged conductor; but the fact that insulation retards evaporation, shows that electricity is a necessary agent.

The electricity of steam also supports this theory. See article on that subject, page 141, Vol. II.

or clouds, thus causing a vacuum in the regions of the clouds, and the air, from its elasticity, rising to fill the vacuum, decreases the pressure on the mercury.

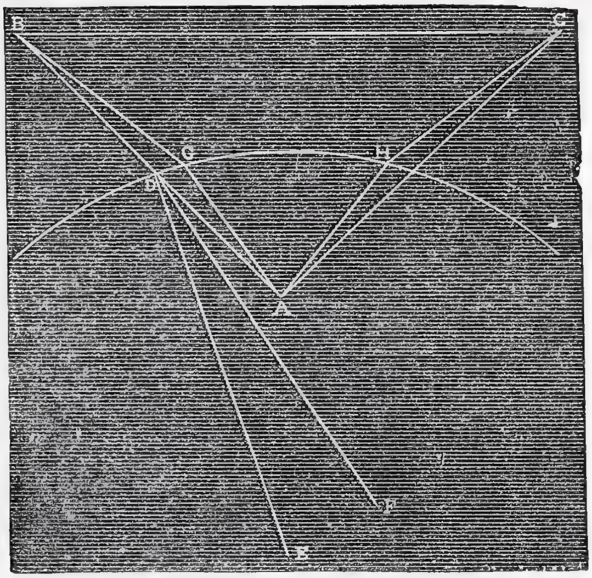
Storms, in most cases, I believe, are from similar causes: the enormous and rapid escape of electricity from clouds during heavy rains, causes a rarefaction of the air in the clouds; the air between the clouds and the earth rushes upwards to fill the rarefied space, and the air at the earth's surface rushes in from all points to gain its equilibrium; and when the excessive rains, which take place at times in tropical climates, are borne in mind, I think the causes explained will be sufficient to account for the most terrific storm.

APPARENT MAGNITUDE OF HEAVENLY BODIES.

Simple as the subject may appear, we have never seen it satisfactorily explained in our common works on the phenomena of light and refraction, why the sun appears so much larger when it is near the horizon than at any other time of the day, and why it appears sometimes to vary in magnitude at the same altitude.

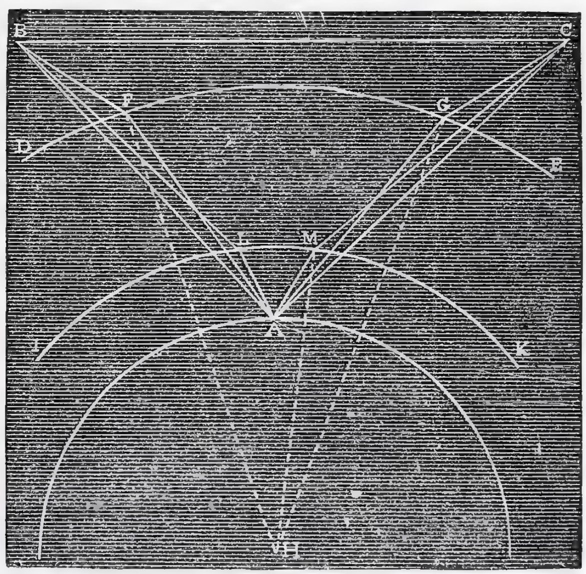
If there were no atmosphere surrounding the earth, the sun, or moon, seen near the horizon, would appear less than when seen in the zenith, because being more distant by the earth's semidiameter, it would subtend a smaller angle. But the effect of atmospherical refraction on these bodies is not only to cause them to appear in a place different from their true place, but also under a smaller angle. The atmosphere diminishes the angle under which all bodies are viewed, the rays from which traverse it—the diminution of the visual angle, however, is so much the less, as the depth of the atmosphere is greater; and hence, the angle under which a body would be seen if there were no atmosphere, is more diminished in the zenith than on the horizon—so that a body in the latter circumstances appears larger from this cause. Now, these two influences seem exactly to counterbalance each other, for the diameter of the moon, as measured by an instrument, is the same, whether viewed on the horizon, or at a distance from it. Nevertheless, the impression left on our senses is, that it is much larger when it rises than when it souths. Now, as we judge of the size of bodies from the magnitude of the angle which they subtend, taken in connexion with our idea of their distance, it follows that, if we are wrong in our estimate of the latter element, we shall form a false judgment of a body's magnitude. This happens in the case in question, and the greater size of the sun or moon on the horizon, is an optical illusion, arising from our fancying these bodies much more remote from us when on the horizon, than they are when they approach the zenith. This explanation was first proposed by Alhazen, an Arabian writer, and it may be interesting to give his own statement of it. After recapitulating that the eye judges of the magnitude of visible objects by comparing the visual angles under which they are seen with their distance, and, that if it does not form a true judgment of the distance of objects, it will not form a just estimate of their magnitude; he proceeds to say:—That the sight perceives the colour of the sky, but not its form, by the unassisted sense, and whenever it perceives any colour extended in length and breadth, without discerning its true form, it conceives of it as a flat, and likens it to an ordinary surface, as for instance a wall. In this manner it apprehends convex and concave surfaces when very remote. The eye thus judges of the surface of the heavens as of a plane, and of the stars as of ordinary visible objects spread over an extensive space; and when it views objects in any wide range, and sees them under equal angles, and at the same time forms an estimate of their visible distances, that which is most remote will appear the greatest. As the eye, therefore, apprehends the surface of the heavens as a plane, not perceiving its concavity, and considers the stars as spread over it—it considers equal stars as unequal in different positions—for it compares the angle which a distant star in the neighbourhood of the horizon subtends at the centre of vision with a remote distance, and it compares the angle which the star subtends in the middle of the sky with a near distance, and thus estimates a star which is on the horizon as greater than one which is in the zenith. It apprehends, therefore the same star and the same distance in different parts of the heavens as of different magnitude. This account of the phenomenon has been generally received by astronomers ever since. The celebrated Huygens, in his Treatise on Parhelia, as translated by Dr Smith, says:—The cause of this fallacy in short is this, that we think the sun, or anything else in the heavens, to be remote from us, when it is nearer the horizon, than when it approaches towards the vertex, because we imagine everything in the air that appears near the vertex, to be no further from us than the clouds that fly over our heads, whereas, on the other hand, we are used to observe a large tract of land lying between us and the objects near the horizon, at the far end of which the convexity of the sky begins to appear, which, therefore, with the objects that appear in it, we usually imagine to be much further from us. Now, when two objects of equal magnitudes appear under the same visual angle, we always judge that object to be larger which we think is remoter. And this is the true cause of the deception we have been speaking of.

Prop. I.—The angle which a heavenly body subtends at the eye is diminished by the refraction of the atmosphere.



Let the eye be in A, and let B C be the diameter of the body seen; D G H, the spherical boundary of the atmosphere whose centre is E, beyond A.

If there were no atmosphere, B C would subtend the angle



B A C, but the ray B A, when it reaches D, is refracted towards the perpendicular, and takes the direction D F, and so passes the eye. Whereas the ray, emanating from B, which does enter the eye,

is that which, arriving at the surface of the atmosphere in the direction B G, suffers the deflection in G, necessary to give it the direction G A. And, as the same takes place with the ray from C, B C will be seen under an angle G A H, less than the angle B A C.

Prop. II.—Although the heavenly bodies, seen from the surface of the earth, must appear less from the effect of refraction, yet, the extent to which the visual angle is diminished, will vary according as the limit of the atmosphere is more or less distant from the eye. The diminution of the visual angle will be less as the distance of this limit is greater.

If in the second figure, the limit of the atmosphere, in place of being I K, were D E, the visual angle B A C would become F A G; for the rays B F, C G, in approaching the perpendiculars F H and G H, unite in A. But they would not meet there if the limit of the atmosphere were I K, for, not suffering refraction at the points, F and G, they would pass the eye, and the visual angle would be formed by other rays, B L and C M, which, after being refracted in the inferior atmosphere I K, meet in A, and form an angle L A M less than the angle F A G, which would have resulted from refraction at the more distant limit D E. Hence, it follows, that the heavenly bodies must appear the greater the more remote the limit of the atmosphere.

The second part of the question with which we began our remarks, is sufficiently well explained by reference to the different states of the atmosphere at different times, as regards moisture and warmth, both of which greatly influence its refractive power.—See Article on Refraction of Light, Vol. I. p. 257.

ON THE RATIO BETWEEN THE FORCE AND THE VELOCITY OF HEAVY BODIES IN MOTION.

The question about to be considered constitutes the very foundation of mechanical science. It might therefore be supposed, considering the present advanced state of the mechanical arts, that there could exist little difference of opinion on the subject; at all events, among those whose profession required that they should have an accurate knowledge of the science. The real state of matters, in this respect, is, however, very different. And the conflicting and erroneous opinions are not confined to the workshops of the mechanic; but are to be found in the transactions of Associations which number amongst their members many of the most scientific men, and most eminent engineers in the kingdom.

The first difference of opinion, respecting the force of bodies in motion, is to be traced so far back as the days of Sir Isaac Newton. Soon after the publication of the Principia, several philosophers, among whom was the celebrated Leibnitz, objected to the second law of motion, as therein expressed, viz., "*Every change of motion is proportional to the force impressed and is made in the direction of that force.*" The supporters of the Leibnitzian measure of moving force maintained, that the force increased as the square of the velocity; and adduced in proof of this position, that a bullet moving twice as fast will penetrate four times as far, and will require four times the quantity of powder—that is, four times the force, to communicate the double velocity; that a body propelled directly upward with a double velocity, will rise four times as high, against the uniform resistance of gravity. Thus, a body impelled with a velocity of 32 feet per second will rise through a height of 16 feet; but with a velocity of 64 feet per second, it will rise through a height of 64 feet; and with a velocity of 96 feet, it will rise through a height of 144 feet; that is, the heights will be in proportion to the squares of their respective velocities: the double velocity rising to four times the height, and the treble velocity carrying the body to nine times the height. These, and several other facts of a similar nature, were adduced in support of this theory.

The party, on the other hand, who maintained that the force should be estimated in the simple ratio of the velocity, observed, that forces generate velocities in proportion to the time they act, and in proportion to their intensity. Thus, a body falling freely by the action of gravity, acquires a velocity of about 32 feet per second at the end of the first second of its fall; and 64 feet per second at the end of the second, and 96 the third, and so on; increasing in velocity 32 feet per second during each second of its fall. It is also proved, and admitted, that if the force of gravity were half or double what it is, the velocities generated in an equal time would be half or double, just in proportion to the forces producing them.

It may be observed, that the party last referred to consider pressure or force, and the *time* it has acted, as the measure of moving force, although they admit the objections already quoted, and several others of a similar nature. But perhaps this side of the question will be best illustrated from the works of an advocate of the doctrines held by the party. The following quotations are from Robison's Mechanical Philosophy, a work of acknowledged merit. The edition quoted from was edited by Sir David Brewster, and published in 1822. Referring to the Leibnitzian party, the author observes:—

"The philosophers who have so strenuously maintained the other measure of force, are among the most eminent of those who have examined the motions produced by gravity, magnetism, electricity, &c.; and they never think of measuring these forces any other way than by the velocity. It is in this way that the whole of the celestial phenomena are explained in perfect uniformity with observation, and that the Newtonian philosophy is considered as a demonstrative science.

"There must, therefore, be some defect in the principle on which the other measurement of force is built, or in the method of applying it. Pressure is undoubtedly the immediate and natural measure of force; yet we know that four springs, or a bow four times as strong, gives only a double velocity to an arrow.

"The truth of our law rests on this only, that we assume the changes of motion as the measure of the changing forces; or, at least, as the measures of their exertions in producing motion. In fact, they are the measures only of a certain circumstance, in which the actions of very different natural powers may resemble each other; namely, the competency to produce motion. They do not perhaps measure their competency to produce heat, or even to bend springs. We can surely consider this apart from all other circumstances; and it is worthy of separate consideration. Let us see what can be, and what ought to be, deduced from this way of treating the subject.

"The motion of a body may certainly remain unchanged. If the direction and velocity remain the same, we perceive no circumstance in which its condition, with respect to motion, differs.

"Its change of place or situation can make no difference; for this is implied in the very circumstance of the body's being in motion.

"But if either the velocity or direction change, then surely is its mechanical condition no longer the same; a force has acted on it, either intrinsic or from without, either accelerating, or retarding, or deflecting it. Supposing the direction to remain the same, its difference of condition can consist in nothing but its difference of velocity. This is the only circumstance in which its condition can differ, as it passes through two different points of its rectilineal path. It is this determination by which the body will describe a certain determinate space uniformly in a given time, which defines its condition as a moving body: the changes of this determination are the measures of their own causes,—and to these causes we have given the name *force*. These causes may reside in other bodies which may have other properties, characterized and measured by other effects. Pressure may be one of those properties, and may have its own measures: these may, or may not, have the same proportion with that property which is the cause of a change of velocity, and therefore changes of velocity may not be a measure of pressure. This is a question of fact, and requires observation and experience: but in the mean time, velocity, and the change of velocity, is the measure of moving force, and of changing force. When therefore the change of velocity is the same, whatever the previous velocity may be, the changing force must be considered as the same; therefore, finally, if the previous velocity is nothing, and consequently the change on that body is the very velocity or motion that it acquires, we must say that the force which produces a certain change in the velocity of a moving body, is the same with the force which would impart to a body at rest a velocity equal to this change or difference of velocity produced on the body already in motion."

Some of the above remarks are perhaps rather metaphysical. Following out the same views at page 65, the author proceeds to

suggest some doubts, "whether *pressures* in their exertion, while they produce motion, or changes of motion, continue to be the same as when they do not produce motion, being withstood or balanced by opposite pressures." The following facts are brought forward as affording proofs that no such change takes place, and also in objection to the opposite theory which supposes and involves the necessity, that a greater force is required to produce any given change of motion when the velocity of the moving body is greater. "A clay ball, moving six feet per second, will make the addition of one foot to the velocity of an equal clay ball that is already moving four feet per second in the same direction. But if this last ball be already moving ten feet per second, we must follow it with a velocity of twelve feet, in order to increase its velocity one foot. But without insisting on the numberless paralogisms and inconsistencies which this way of conceiving the matter would lead us into, it suffices to observe that the phenomena give us abundant assurance that there has been the same exertion in both these cases. This acceleration is always accompanied by a compression of the balls, and the compression is the same in both. This compression is a very good measure of the force employed to produce it; and in the present case we need not even trouble ourselves with any rule for its measurement, for surely when the compression is not different, the force exerted is the same. This is farther confirmed by observing, that it requires the same force to make the same pit in, or to give the same motion to, a piece of clay lying on the table of a ship's cabin, whether the ship be sailing two or ten miles per hour."

In continuation of this subject, page 77, the author, referring to the fact of the relative motions of bodies not being affected by any motion common to all, observes :—

"Thus it is that the same strength of a bow will communicate a certain velocity to an arrow, whether it is shot east, or west, or north, or south. Thus it is that the mutual actions of sublunary bodies are the same, in whatever directions they are exerted, and notwithstanding the very great changes in their velocities by reason of the earth's rotation and orbital revolution. The real velocity of a body on the earth's equator is about 3000 feet per second greater at midnight than at mid-day, for at midnight the motion of rotation conspires with the orbital motion, and at mid-day it nearly opposes it. The difference between the velocities at the beginning of January, and the beginning of July, are vastly greater. And at other times of the day, and other seasons of the year, both motions of the earth are transversely compounded with the easterly or westerly motion of an arrow or cannon bullet. Yet we can observe no change in the effects of the mutual actions of bodies.

"This is an important observation, because it proves that forces are to be measured by no other scale than by the motions which they produce. We have had repeated occasion to mention the very different estimation of moving forces by Mr Leibnitz, and have shown how, by a very partial consideration of the action of those natural powers called *pressures*, he has attempted to prove, that moving forces are proportional to the squares of the velocities; and we showed briefly, in what manner a right consideration of what passes when motion is produced by measurable pressures, proves that the forces really exerted are as the velocities produced. But the most copious proof is had from the present observation, that, in fact, the mutual actions of bodies depend on their relative motions alone.

"The Leibnitzian measure of moving force is altogether incompatible with the universal fact now mentioned, viz., that the relative motions of bodies, resulting from their mutual actions, are not affected by any common motion, or the action of any equal and parallel force on both bodies; for this universal fact imports, that when two bodies are moving with equal velocities in the same direction, a force applied to one of them, so as to increase its velocity, gives it the same motion relative to the other, as if both bodies had been at rest. Here it is plain, that the space described by the body in consequence of the primitive force, and of the force now added, is the sum of the spaces, which each of them would generate in a body at rest. Therefore the forces are proportional to the velocities, or changes of motion which they produce, and not to the squares of these velocities. This measure of forces, or the position that a force makes the same change on any velocity whatever, and the independence of the relative motions on any motion that is the same on all the bodies of a system, are counterparts of each other. Since this independence is a matter of observation in all terrestrial bodies, we are entitled to say, that the powers which the Author of nature has imparted to natural bodies are no way different from what are competent to matter once called into existence; and it also follows from this, that we must always remain ignorant of the absolute motions of bodies. The fact, that it has required the unremitted study of ages to discover even the relative motion of our solar system, is an argument to prove, that the influence of this mechanical principle extends far beyond the limits of this sublunary world; nor has any phenomenon yet been exhibited, which should lead us to imagine that it is not universal.

"When we have made use of these arguments with some zealous partisans of Mr Leibnitz's doctrine, they have answered, that if indeed this independence of the relative motions of terrestrial bodies were observed to obtain exactly, it would be a conclusive argument. But the motion with which all is carried along is so great, in comparison with the motions which we can produce in our experiments, that the small additions or diminutions that we can make to the velocity of this common motion, must observe very nearly the proportions of the additions or diminutions of their squares. The difference of the squares of 2, 3, and 4, are very unequal; but the differences of the squares of 9, 10, and 11, are much nearer to the ratio of equality, and the difference of the squares of 1000001, 1000002, 1000003, do not sensibly deviate from this ratio. But it is not fact that we cannot produce motions which have a very sensible proportion to the common motion. The motion of a cannon ball, discharged with one-third of its weight of powder, is nearly equal to that of the rotation of the earth's equator. When, therefore, we discharge the ball eastward, we double its motion; when to the westward, we destroy it. Therefore, according to Leibnitz, the action in the first case is three times the action in the second.—In the first case it changes the square of the velocity (which we may call 1) from 1 to 4; and, in the second, it changes it from 1 to 0. But say the Leibnitzians, the velocity of rotation is but $\frac{1}{63}$ of the orbital velocity of the earth, and our observations of the velocities of cannon bullets are not sufficiently exact to ensure us against an error of $\frac{1}{31\frac{1}{2}}$. But the later observations on the peculiar motions of the fixed stars concur in showing, that the sun, and his attending planets, are carried along with a very great motion, which, in all probability, has a sensible ratio to the orbital motion of the earth. This must make a prodigious change on the earth's absolute motion, according as her orbital motion conspires with, opposes, or crosses this other motion; the earth may even be at absolute rest in some points of its orbit. Thus will the composition, with the motions produced in our experiments be so varied, that cases *must* occur when the difference of the results of the two measures of force will be very sensible.

"But, farther, they have not attended to the agreement of our experiments, when the discharges of cannon are made in a direction transverse to that of the common motion. Here the immensity of the common motion, and the minuteness of our experimental velocities, can have no effect in diminishing the difference of the results of the two doctrines."

The latter observations are worthy of particular attention. In order to illustrate this subject—suppose a person placed near the earth's equator at midnight to impart a velocity of 32 feet per second to a body weighing 10 lbs. In this position the body is already carried in an easterly direction by the earth's orbital and rotatory motion, with a velocity of about 91,400 feet per second. Hence, if the body be impelled eastward with a velocity of 32 feet per second, its absolute velocity is increased from 91400 to 91432 feet per second. Now, if the forces are proportional to the squares of the velocities, then the quantity of force added in producing this increase of 32 feet per second, is equal to five thousand seven hundred and thirteen times the force which would be required to produce a velocity of 32 feet per second, from a state of absolute rest. Or it would require a force rather greater than that obtained from a one horse power steam-engine acting to the greatest advantage during twenty minutes. But if the body be impelled north or south, or in any direction at right angles to the direction of its absolute motion, then the absolute velocity is very little increased, and the quantity of force required in this case is the same as that which would produce the velocity from a state of absolute rest.

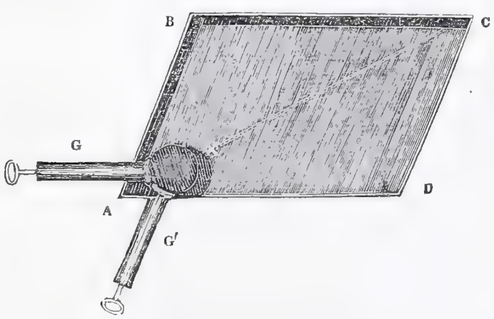
These deductions are at first sight rather startling. An at-

tempt will be made, however, before concluding this subject, to show that the theory of the forces being as the squares of the velocities, is perfectly reconcilable with observation, and consistent with itself.

In the foregoing illustrations it is assumed that our planetary system has no progressive motion in space; but however this may be, motions are produced in all directions on the surface of the earth, and the result must, at some parts of the earth's orbit, be at least as great as these stated. Before concluding the present article, it may be proper to refer, shortly, to the manner in which this subject is treated in the generality of the elementary works on natural, or mechanical philosophy, of a modern date, which have been published for the instruction of mechanics and others, in the principles of their professions. The consideration of this subject is, by many of these publications, in a great measure avoided; or, it is treated in such a manner as to be more likely to mislead than to impart the true principles to the mind of the student. The mechanic is still taught that *momentum*, or moving force, is to be estimated by the product of the mass into the velocity simply; and the reflecting reader is sometimes not a little surprised, when he finds the same authority directing him to estimate the momentum, or moving force of a fly-wheel, by multiplying the mass by the square of its velocity. Indeed, there are not wanting instances of engineers of extensive practice rebelling against this rule, and calculating the momentum of their fly-wheels in the simple proportion of the velocity. In doing so, they have calculated the regulating power of the fly inaccurately, but the fault lies more with their scientific instructors than with themselves.

The following quotation, from the treatise on mechanics, in the "Library of Useful Knowledge," will illustrate the erroneous views, that men of considerable acquirements have been led to entertain on the subject; and also the erroneous doctrines that are set before the mechanic, under the name of useful knowledge:—

"Let a level table A, B, C, D, in the form of a parallelogram, be provided, furnished with a ledge to prevent a ball from rolling off; and let two spring guns, G, G′, be placed at one of the corners A, so that when G strikes the ball, X, it shall move along the side, A D, in a certain time, and when G′ strikes the ball, it shall move along A D in the same time. Now, if both the guns strike X at the same instant, it will be found to move along the diagonal A C, and to do so exactly in the same time as, by the impulse of each gun separately, it moved along the sides."



In following out the principle here asserted to be true, it is evident, that as the springs are made to act nearer in the same direction, the diagonal A C increases until it is finally equal to the two sides. Two equal springs would therefore produce a double velocity. But it has been proved by experiment, and admitted by those of both parties who have attentively examined the subject, that it requires four equal springs to produce a double velocity. To make our meaning still clearer:—The angle, B A D, may be supposed to be diminished to any extent; and this may be carried so far that the sides, A B, A D, shall coincide. In that case, A B, B C, would coincide with A C; or, in other words, the sum of the two sides would be equal to the length of the diagonal, A C. The two guns would then impel the ball in the same direction; and if the rule above stated were true, it would acquire a double velocity, so as to pass over twice the distance in the same time as when impelled by only one of the guns, that is to say, it would pass along A C ($=$ A B $+$ B C $=$ A B $+$ A D), in the same time as it would pass along A B or A D, when impelled by one of the guns. But this is proved not to be the case. To double the velocity, the force must be quadrupled; that is to say, the velocity produced is as the square of the force applied. The proposition above laid down would be true only if the springs acted at right angles to each other; and the diagonal in this case would represent the greatest velocity that the springs are capable of producing in whatever manner or direction they acted: moreover, this velocity of the ball would be capable of again compressing the spring, and if it were more, the effect would be greater than the cause.

SAFETY APPARATUS FOR HIGH-PRESSURE BOILERS.

Numerous forms of safety-valves have been contrived, some of which possess great merit, and many more exhibit ingenuity. They have, however, all their defects, from the most complicated down to fusible plugs.

A new plan has been proposed, which consists in a combination of the safety-valve and the fusible plug, and is founded upon Bache's well-known contrivance. The object to be attained is twofold. In the first place, the apparatus is intended to prevent the pressure of steam becoming too great for the strength of the boiler; and in the next, to prevent the crown of the fire-box getting burned without due intimation of the mischief going on.

To effect these important objects, it is proposed, in the first place, to place upon the top of the fire-box a short tube with a stalk passing through the plate; it may be fastened by rivetting or otherwise. Into the open end of this tube the end of a rod with a flange upon it is introduced nearly to the bottom. The tube is then filled completely with an alloy, in a state of fusion, whose melting point corresponds with the temperature of the highest pressure of steam which is reckoned consistent with the safety of the particular boiler to which the apparatus is to be applied. The alloy being allowed to become solid by cooling, the mouth of the tube is then to be covered by a thin plate of brass, passed over the upright rod, which is now held fast at its lower end by the metal in the tube. The disc of brass is to be fitted in its place quite steam-tight, but still in such a way that it may readily be displaced upwards. This part of the apparatus is then complete; and it only remains to attach the top of the rod to a valve of appropriate size, in the top of the boiler. This valve must be held in its seat by the rod alone, and may be conveniently fastened by screwing the end of the rod, and passing a nut upon it, above the valve. The whole being thus made tight, a perforated cover may be placed over the valve to prevent any interference with it.

The apparatus being thus completed, its mode of action will be this: so long as there is a sufficiency of water in the boiler, and the temperature less than that necessary to fuse the alloy in the tube, the apparatus gives no indication; under these circumstances it is not intended to act. But should the water become low, and the crown of the fire-box begin to get over-heated, the heat would be conducted through the stem connecting the tube with the crown-plate to the metal within it, and render it liquid; the immediate consequence of this would be the displacement of the valve by the steam-pressure within the boiler; for the instant the fusible alloy, which alone binds it down by means of the rod, becomes liquid, all obstacle to its displacement is removed. Again; should the water or steam surrounding the tube become heated to a dangerous temperature, the alloy would similarly be melted, and the same result would follow.

From this it will be observed that the apparatus is intended not for common use, but as a *dernier ressort*—a last intimation that imminent danger is impending. In fact, to bring it into action would itself be reckoned a misfortune by the engineer; for it would require immediate re-adjustment, which could not be effected without some trouble. Perhaps the readiest way of doing this would be to loose the nut slightly, and, applying a hot bolt to the side of the tube to melt the alloy, insert the rod as before; after cooling, the apparatus could be tightened up and its cover placed over it, when it would again be in order for averting the next calamity that threatened.

The tube ought to be made somewhat narrower at the mouth than at the bottom; and both it and the stem by which it is attached to the crown plate ought to be of copper, this being a better conductor of heat than iron, and not nearly so readily oxidated. The object of making the tube steam-tight is to protect the alloy from the action of the steam, which is known to alter its constitution, and render its fusing point less certain.

The apparatus might, of course, be applied to other boilers than those of the particular construction here referred to, and even to low-pressure boilers, but not with equal advantage.

EXPERIMENTAL RESULTS AS TO SOME OF THE CHEMICAL AND PHYSICAL PROPERTIES OF THE ATOMIC ALLOYS OF COPPER AND ZINC, AND OF COPPER AND TIN.

By Robert Mallet, M.R.I.A., Assoc. Inst. C.E., &c.

Table I.—Showing the Chemical and Physical Properties of the Atomic Alloys of Copper and Zinc.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of Experiment.	Chemical Constitution.	Composition by weight per cent.	Atomic Weight, Hydrogen being taken as 1.	Specific Gravity.	Colour.	Fracture.	Ultimate Cohesion, per square Inch in Tons.	Order of Ductility.	Order of Malleability at 60° Fahrenheit.	Order of Hardness, &c.	Order of Fusibility.	Characteristic Properties, in Working, &c.	Relation to Cast-Iron, in presence of a solvent, *i. e.* Sea Water.
1	C. +	100·00 + 0	31·6	8·667	Tile Red.	E.	24·6	8	1	22	15	Well known.	All these Alloys increase the Corrosion of Cast Iron in Sea Water, when in their presence.
2	10 C. + Z.	90·70 + 9·30	348·3	8·605	Reddish yellow, 1	C.C.	12·1	6	13	21	14		
3	9 C. + Z.	89·80 + 10·20	316·7	8·607	Reddish yellow, 2	F.C.	11·5	4	11	20	13	Similor, &c. { Several of these are malleable at high temperatures.	
4	8 C. + Z.	88·70 + 11·30	285·1	8·633	Reddish yellow, 3	F.C.	12·8	2	10	19	12		
5	7 C. + Z.	87·70 + 12·30	253·4	8·587	Reddish yellow, 4	F.C.	13·2	9	9	18	11		
6	6 C. + Z.	85·08 + 14·92	221·9	8·591	Yellowish red, 3	F.F.	14·1	5	8	17	10		
7	5 C. + Z.	83·02 + 16·98	190·3	8·415	Yellowish red, 2	F.C.	13·7	11	2	16	9	Bath Metal.	
8	4 C. + Z.	79·65 + 20·35	158·7	8·448	Yellowish red, 1	F.C.	14·7	7	3	15	8	Dutch Brass.	
9	3 C. + Z.	74·58 + 25·42	127·1	8 397	Pale yellow.	F.C.	13·1	10	4	14	7	Rolled Sheet Brass.	
10	2 C. + Z.	66·18 + 33·82	95·5	8·299	Full yellow, 1	F.C.	12·5	3	6	13	6	British Brass.	
11	C. + Z.	49·47 + 50·53	63·9	8·230	Full yellow, 2	C.C.	9·2	12	5	12	6	German Brass.	
12	C. + 2 Z.	32·85 + 67·15	96·2	8·283	Deep yellow.	C.C.	19·3	1	7	10	6	Brass, Watchmakers.	
13	8 C. + 17 Z.	31·52 + 68·48	801·9	7·721	Silver white, 1	C.	2·1	0	22	5	5	Very Brittle, { Too hard to file or turn, lustre nearly equal to Speculum Metal.	All these Alloys decrease the Corrosion of Cast Iron in Sea Water, when in their presence.
14	8 C. + 18 Z.	30·30 + 69·70	834·2	7·836	Silver white, 2	V.C.	2·2	0	23	6	5	Very Brittle,	
15	8 C. + 19 Z.	29·17 + 70 83	866·5	8·019	Silver grey, 3	C.	0·7	0	21	7	5	Very Brittle,	
16	8 C. + 20 Z.	28·12 + 71·88	898·8	7·603	Ash grey, 3	V.	3·2	0	19	3	5	Brittle,	
17	8 C. + 21 Z.	27·04 + 72·96	931·1	8·058	Silver grey, 2	C.	0·9	0	18	9	5	Brittle,	
18	8 C. + 22 Z.	26·24 + 73·76	963·4	7·882	Silver grey, 1	C.	0·8	0	20	8	5	Very Brittle,	
19	8 C. + 23 Z.	25·39 + 74·61	995·7	7·443	Ash grey, 4	F.C.	5·9	0	15	1	5	Barely Malleable.	
20	C. + 3 Z.	24·50 + 75·50	128·5	7·449	Ash grey, 1	F.C.	3·1	0	16	2	4	Brittle.	
21	C. + 4 Z.	19·65 + 80·35	160·8	7·371	Ash grey, 2	F.C.	1·9	0	14	4	3	White Button Metal.	
22	C. + 5 Z.	16·31 + 83 69	193·1	6·605	Very dark grey.	F.C.	1·8	0	17	11	2	Brittle.	
23	+ Z.	0 +100·00	32·3	6·895	Bluish grey.	T.C.	15·2	13	12	23	1	Brittle, well known.	

Table II.—Showing the Chemical and Physical Properties of the Atomic Alloys of Copper and Tin.

1	C. +	100·00 + 0	31·6	8·667	Tile Red.	E.	24·6	1	2	10	16	Well known.	Every Alloy of C. + T. increases the Corrosive action of Sea Water on Cast Iron, in their presence; the maximum increase is due to Tin.
2	10 C. + T.	84·29 + 15·71	374·9	8·561	Reddish yellow, 1	F.C.	16·1	2	6	8	15	Gun Metal, &c.	
3	9 C. + T.	82·81 + 17·19	343·3	8·162	Reddish yellow, 2	F.C.	15·2	3	7	5	14	Gun Metal, &c.	
4	8 C. + T.	81·10 + 18·90	311·7	8·459	Yellowish red, 2	F.C.	17·7	4	10	4	13	Gun Metal and Bronze.	
5	7 C. + T.	78·97 + 21·03	280·1	8·728	Yellowish red, 1	V.C.	13·6	5	11	3	12	Hard Mill Brasses, &c.	
6	6 C. + T.	72·27 + 27·73	248·5	8·750	Bluish red, 1	V.	9·7	0	12	2	11	Brittle, { All these Alloys found occasionally in Bells, with mixtures of Zinc and Lead.	
7	5 C. + T.	72·80 + 27·20	216·9	8·575	Bluish red, 2	C.	4·9	0	13	1	10	Brittle,	
8	4 C. + T.	68·21 + 31·79	185·3	8·400	Ash grey.	C.	0·7	0	14	6	9	Crumbles,	
9	3 C. + T.	61·69 + 38·31	153·7	8·539	Dark grey.	T.C.	0·5	0	16	7	8	Crumbles,	
10	2 C. + T.	51·75 + 48·25	122·1	8·416	Greyish white, 1	V.C.	1·7	0	15	9	7	Brittle,	
11	C. + T.	34·92 + 65·08	90·5	8·056	Whiter still, 2	T.C.	1·4	0	9	11	6	Small Bells, Brittle.	
12	C. + 2 T.	21·15 + 78·85	149·4	7·387	Whiter still, 3	C.C.	3·9	0	8	12	5	" Brittle.	
13	C. + 3 T.	15·17 + 84·83	208·3	7·447	Whiter still, 4	C.C.	3·1	0	5	13	4	Speculum Metal of Authors	
14	C. + 4 T.	11·82 + 88·18	267·2	7·472	Whiter still, 5	C.C.	3·1	8	4	14	3	" Files, Tough.	
15	C. + 5 T.	9·68 + 90·32	326·1	7·442	Whiter still, 6	E.	2·5	6	3	15	2	" Files, Soft & Tough.	
16	+ T.	0 +100·00	58·9	7·291	White, 7	F.	2·7	7	1	16	1	Well known.	

Abbreviations used in column 7th to denote character of Fracture:—F.C. Fine Crystalline, C.C. Coarse Crystalline, T.C. Tabular Crystalline, F.F. Fine Fibrous, C. Conchoidal, V.C. Vitreo-Conchoidal, V. Vitreous, E. Earthy.

The maxima of ductility, malleability, hardness, and fusibility, are = 1.

The numbers in column 6th denote intensity of shade of the same colour.

The atomic weights are those of the hydrogen scale.

The specific gravities were determined by the method indicated in report "On Action of Air and Water on Iron." Trans. Brit. Ass., vol. vii., p. 283.

The ultimate cohesion was determined on prisms of 0·25 of an inch square, without having been hammered or compressed after being cast. The weights given are those which each prism just sustained for a few seconds before disruption.

The copper used in these alloys was granulated, and of the finest "tough pitch;" the zinc was Mosselman's from Belgium; and the tin "grain tin," from Cornwall. They were alloyed in a peculiar apparatus, to avoid loss by oxidation, and the resulting alloy verified by analysis.

No simple binary alloy of copper and zinc, or of copper and tin, works as pleasantly in turning, planing, or filing, as if combined with a very small proportion of a third fusible metal —generally lead is added to C. + Z., and Zinc to C. + T., as is known to workers in metals.

ACCOUNT OF THE GREAT CHIMNEY AT THE ST. ROLLOX CHEMICAL WORKS, GLASGOW.

By Professor Gordon and Lawrence Hill, C.E., of Glasgow.

The great chimney at St. Rollox, Glasgow, was erected in order to carry off the muriatic acid, and other gases, escaping in the works, at such a height that, before the gases could fall, they should be so diluted as to be innocuous. The peculiar construction of the chimney, viz., a double cone was adopted, in order to maintain the heat of the gases as long as possible; and at the same time the internal form of the chimney and its dimensions are such, that there should be a maximum discharge for the same temperature of the ascending column. The chimney perfectly accomplished this end; but soon after its erection, the process in which the muriatic acid is disengaged, was so conducted, that the whole gas is now collected, condensed, and applied to useful purposes, or run off; and thus the great function of the chimney's enormous height is no longer brought into use.

It may be mentioned, that 120 tons of coals are consumed per day in St. Rollox Works, the whole product of the combustion of which goes up the chimney, drawn, in some cases, from a distance through flues 400 yards long. The chimney was designed with a curved batter, the curve being the logarithmic curve; but it was not so built, from some error in setting out the work at its commencement, Mr Gordon being at the time absent.

The following are its exact dimensions:—

Total height from foundations, .	447 feet 6 in.
Depth of foundations, . . .	15 ... 0 ...
Total height above the surface,	432 feet 6 in.
Diameter at base, .	45 feet.
... ... surface,	40 ...
... ... top, .	13 feet 6 in.

There are used in its construction 1,250,000 bricks of the first quality, weighing 121 lb. per cubic foot, resisting 63 tons' pressure per superficial foot before *cracking*, and requiring 110 tons to crush them. The brick-work is 3½ bricks at bottom, and 1½ at top. The internal flue is 260 feet high, *and is perfectly vertical.*

It took six months, in two different seasons, autumn 1841, and spring 1842, to build it, which was accomplished without the slightest accident. It was finished in June 1842.

In May 1844, a rent was discovered in one side, about 36 feet long, extending downwards, from a point about 100 feet from the top. This rent was affirmed by some to have been caused by lightning. The rent gradually increased during June and July, and then a similar rent was discovered on the opposite side, beginning somewhat lower down than the first observed, but extending only 45 feet. This created some apprehension; and, in August, it was determined to examine the chimney where the rents appeared, and, according to the result of this examination, to proceed to measures of security or protection. Scaffolding appeared at first the only means of effecting the desired examination, without stopping the works. Balloons were afterwards proposed, but were considered not so likely a means of accomplishing the end in view, although the celebrated Mr Green, on being applied to, offered the use of a balloon, and his own superintendence of the ascent. During the erection of the chimney, in 1841—while Mr Colthurst, civil-engineer, was superintending the laying of the foundations, and the erection of the first 80 feet of the great chimney—an accident occurred to a chimney of a cotton manufactory in the neighbourhood of St. Rollox, which rendered it highly desirable that some one should go to the top of the chimney. Scaffolding would have cost £20. Mr Colthurst suggested that, by driving *staples* into the joints of the brick-work, a man might be able to climb to the top safely and very cheaply. A man was got who undertook to carry out the suggestion, and actually went up the outside of the chimney 112 feet high, threw down a loose coping-stone from the top, and descended; the whole job occupying two days. Working upon this suggestion of Mr Colthurst, we contrived the Climbing-Machine, for examining the rent in the great chimney, at the height of 280 feet from the ground. The drawings are a correct representation, and show the details of the machine, in which two men worked themselves up 280 feet on the chimney in the course of nine days, including the time occupied in filling up the rent.

Instead of the double-kneed staples on which the climber set his foot, and held on by means of a band with a hook to it, which, passing round his waist, or rather under his arms, supported him while driving in a new staple at the level of his head, or nearly so;—instead of this, in the original, the new machine is so arranged, that two men working in it, bore or "jump" two holes in the brick-work, to receive two lewises. The ropes being hooked on each side, the machine is moved up by means of the ratchets and pall worked by the men. A movement of about 5 feet is thus made. The safety-chains are then put on the pins, or lewises, besides the hooks of the ropes. The men thus secure, go to the top stage of the machine, and, working there, drive each a new hole to receive a new pair of lewises; which being well fixed, the ropes are taken off the lewises, and put on to the new pair. While the machine *was in motion*, the men were at first dependent on the ropes alone, but by attaching the vertical *racks*, which constantly press outwards against the pins, it was very improbable, or scarcely possible, that, even should the ropes break, the machine could fall more than 2 inches before being brought up by the *ratchets* catching on the pins.

On gaining the position of the rent, a strong pulley was fixed in the chimney, through which a rope was passed, extending to the ground; and to this point an ascent can very easily be made at any future time. The persons employed were *slaters* by trade,

Fig. 2.

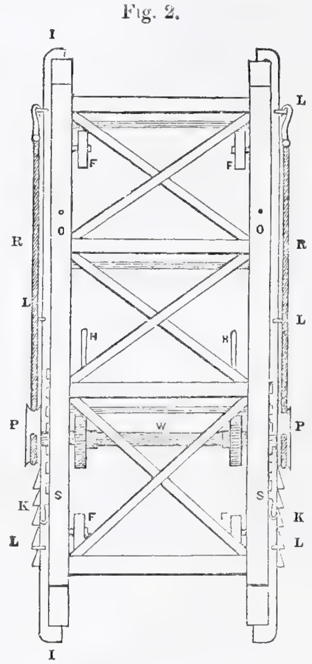


Fig. 1.

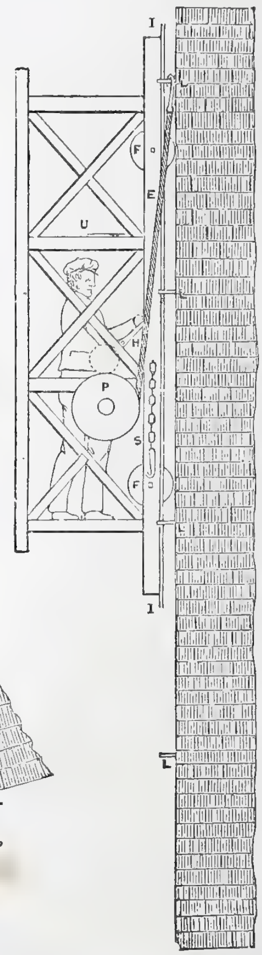
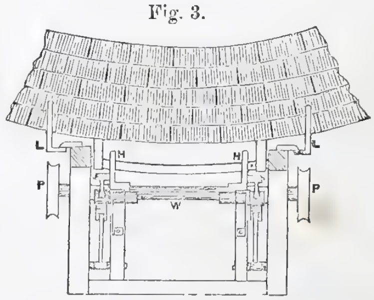


Fig. 3.



Description of the Climbing Machine.

Fig. 1, is a side view.
... 2, is a back view.
... 3, a plan across the windlass.

an old and a young man. It was a principle not to bribe any one to undertake the job. The men worked at wages of 5s. per day, or little more than their ordinary wages. They were steady, sober, active men; and credit is due to them, for the excellent manner in which they did their work, Mr Gordon or Mr Hill went up with the machine each day; and, after careful examination and deliberation, concluded that the rent was an effect of expansion from heat. Though the fissure was found in one place to be 2 inches

wide, and its average width to be nearly 1 inch, yet the nature of it was such, that a rod could not be put through the fissure to the inside of the chimney. It would have been very desirable to have got a thermometer into the interior; but not having succeeded in getting it through the fissure, the expedient of driving a hole for the purpose was not adopted at the time, from its being inconvenient; and so the opportunity was lost. It may be mentioned, however, that *red-hot* matter has been more than once observed protected in a column from the top of this 432 feet high chimney. The temperature in the chimney, near the top, is probably seldom under 600° Fahr.

The frame, which was as light as possible, consistent with proper strength, was about 10 feet high, 3 feet deep, and 4 feet wide; the beams next the stalk projected about 15 inches further at each end. W is the windlass, worked by the ratchet-handles H, H. P, P, two pullies fixed to windlass, round which the ropes were wound when the machine was ascending. L, L, the lewises, securely fixed into the chimney, and to which the ropes were hooked. The heads of these lewises were bent at a right angle, so as to overlap the long plates I, I, by which means the machine was held close to the chimney. F, F, F, F, four friction-rollers, to prevent the machine from rubbing against the stalk. S, S, two short chains, which were used for holding up the machine while the ropes, R, R, were being shifted to a new set of lewises, for another lift. K, K, two long racks, which were hung on pins at O, O. They worked into, or against, the two under lewises, and were used in order to prevent the machine from falling, in case any accident should happen to the ropes.

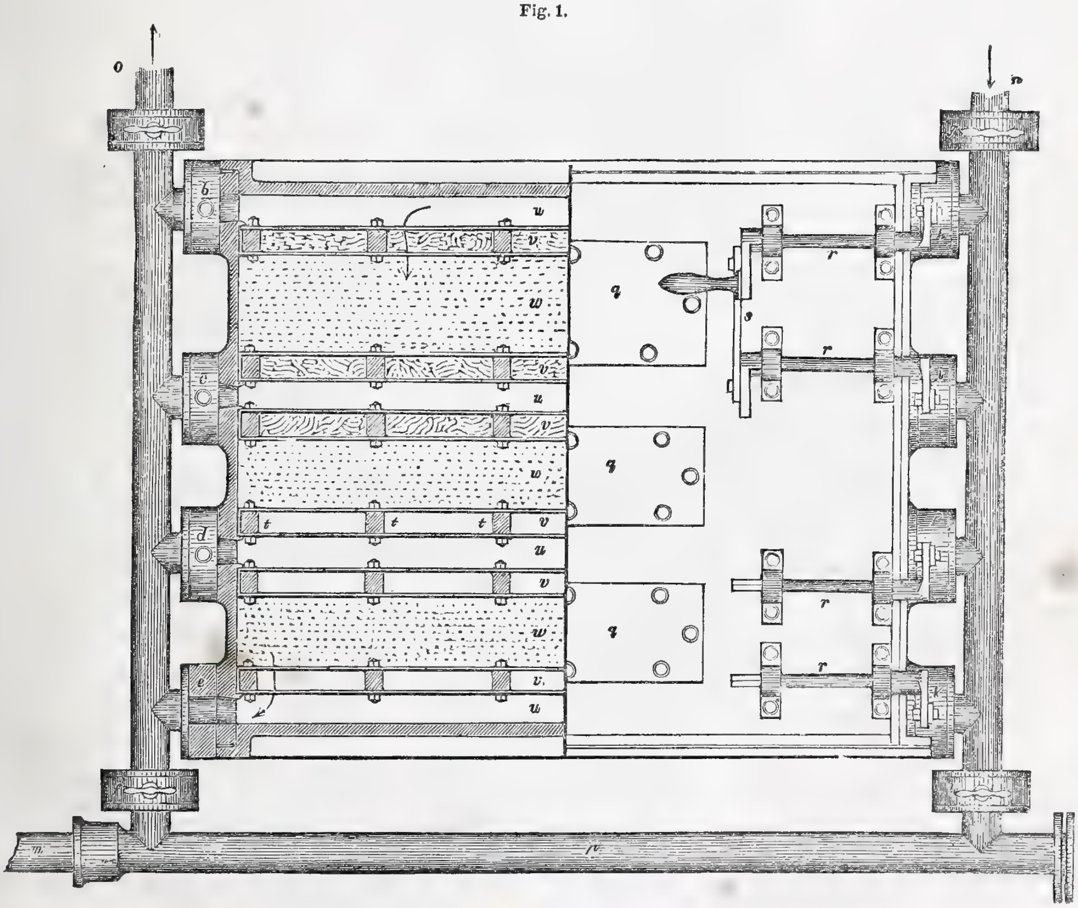
By working the handles backwards and forwards, the machine was sent up a lift of 5 feet in a few minutes. Two catches (not shown in the drawing) worked into the teeth of the windlass wheels, and prevented their recoil. When the men were boring the holes for the lewises in the stalk, they stood on the upper floor or board, U, and the jumpers used to bore the holes were worked through guides fixed to the frame of the machine. At the end of a day's work, the lewises were taken out and used over again in the next day's ascent. The ascent of 280 feet occupied nearly nine days, including the time spent in repairing the rent. The men were hoisted to the cage by a windlass on the ground, the rope from which worked over a large pulley within the machine.

MAURRAS' PATENT FILTER.

A LARGE filter for cleansing the water used by the locomotive engines of the line, has lately been erected at the Cowlairs station of the Edinburgh and Glasgow Railway. As there is some novelty in the apparatus, we here give a drawing and description of it.

The reservoir at this station is partly supplied from a spring in its bed and partly from surface-water, the drainage of the adjacent fields. In rainy weather the surface-water is very muddy, and, before the application of the filter, the mud was, of course, deposited in the boilers of the engines, causing them to prime readily, unless often washed, which had to be resorted to every few days. The filter extracts the earthy matter from the water very effectually, and filters at the rate of 2500 gallons per hour.

Fig. 1.



It is impossible to tell to what extent it has benefitted the passenger engines, as they require to take water at various stations on the line equally as dirty as our unfiltered water. The bank-engines, while using unfiltered water, were speedily fouled, and required to be washed once a week. One of them ran three weeks with the use of filtered water, and when the doors were taken off, the boiler was perfectly clean, excepting a few scales that had been deposited from the spring water, which is impregnated with a small quantity

of lime in chemical combination, an impurity which the filter cannot separate,

This machine, from its small size and portability, is of great importance compared with the ordinary, sluggish system of filtration, as it can be applied in any situation; whereas the other can be used only in certain localities, on account of the great surface required for exposure, while this, by the pressure of a column of water, could be made to filter a great quantity. The only defect in the filter shown in the figure, is its square form, as the pressure springs the sides, causing a portion of the sand in the beds to escape past the edges of the retaining boxes; but to obviate this, the manufacturer is now making them of a cylindrical form, which enables them to sustain the pressure equally on all sides.

Description.—The machine is represented in fig. 1, partly in front elevation, and partly in sectional elevation. The unfiltered water is first of all raised by pumps into a cistern or tank, which stands at an elevation considerably above that of the filter. It then descends from this tank, through the pipe *n*, into the filter; whence, after being purified, it returns by hydrostatic pressure to the main reservoir from which the engines are supplied. The bottom of the reservoir at Cowlairs is 15 feet below that of the tank from which the water descends; there is therefore a pressure of a 15 feet column of water, equal to 7 pounds on the square inch, urging the water through the filter. The two pipes *n* and *o* descend by the sides of the chest to the bottom, where they join the horizontal pipe *p*. They have each four communications with the chest, and the movements of the water are regulated by means of the sluices *a, b, ... l*. The shell of the chest consists of six square plates, bolted together by flanges. The interior is divided into a series of unequal horizontal compartments, *u, v, w*; of these, the compartments *u*, are the water chambers into which the water is admitted from the pipe *n*; the shallow divisions *v*, are the retaining boxes, closely packed with gravel-stones; and the deep divisions *w* are the sand-beds, rammed as solidly as possible with sand. The sand in the upmost bed *w*, is coarser than that in the second bed, and this in like manner is coarser than that in the lowest bed; thus the operation proceeds uniformly and effectively. The purpose of the gravel-beds is to prevent the escape of the sand with the water.

The retaining boxes are formed of two sheet-iron plates, which are galvanised and profusely perforated with small holes for the passage of the water. The plates are kept apart by stiffening frames, shown in section at *t*, and bound together by bolts and nuts. The gravel and sand-beds are filled from openings in front, which are closed by doors *q*, partially shown in the external elevation. Short axles and levers *r*, are put up for working the sluices immediately connected with the chest; they communicate a horizontal motion to the sluices, which consist of wedge-shaped pieces which slide in recesses prepared for them in the interior of the blocks in which they work. To the ends of these taper pieces, are screwed short rods which pass to the outside through stuffing boxes, and are connected to the levers *r* by links. The sluices *a, f, g, l*, have simply handles attached to the rods.

To put the Filter in operation.—The sluices *g, h, e, a*, are opened, all the others being shut; the unfiltered water from the pipe *n*, then flows into the upper water space *u*, descends through the alternate beds of gravel and sand, as indicated by the arrows, and finally flows out through the sluice *e*, into the return pipe *o*, through which it is delivered into the reservoir ready for use.

To wash the Filter with filtered Water.—Shut the sluice *g*; open *e*; and connect by links the levers which work *h, i*, and *b, c*, as shown in the drawing, in such a manner that the sluices, which are diagonally opposed, may be opened or shut together by one turn of the handle placed on either of the axles *r*. The sluices *h* and *c* being opened, the water is allowed to run away by the waste pipe *m*, till it comes off clear. The valves are then reversed, that is, *h* and *c* are shut, and *i* and *b* are opened; by thus suddenly reversing the current of water, the bed of sand is shaken clear of all its impurities. The other beds are washed in the same manner.

It has been stated by the patentee's agent that unless the water be unusually foul, the sand will perform its duty satisfactorily for twelve months; at the end of this time, it has only to be withdrawn by the doors *q*, and washed in an open vessel. Before the sand is replaced, the doors are put on, and the water is sent freely through the retaining boxes above and below each sand-bed to cleanse them thoroughly. The washed sand being then replaced, the filter operates as before.

In the cylindrical filter, the mode of operation is the same as that followed in the square one already described, and, therefore, it will be needless to do more than show the form and working of the cocks. In the cylindrical filter, the supply and return pipes are erected together on one side of the filter; they are connected by cocks opposite each water-space, by turning which one way or the other, a communication may be formed between the supply-pipe or

Fig. 2.

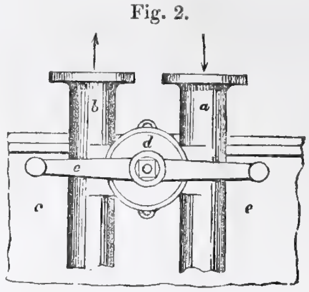
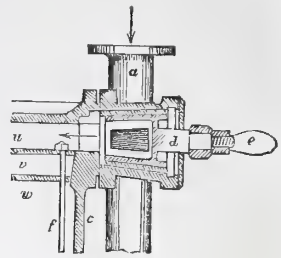


Fig. 3,



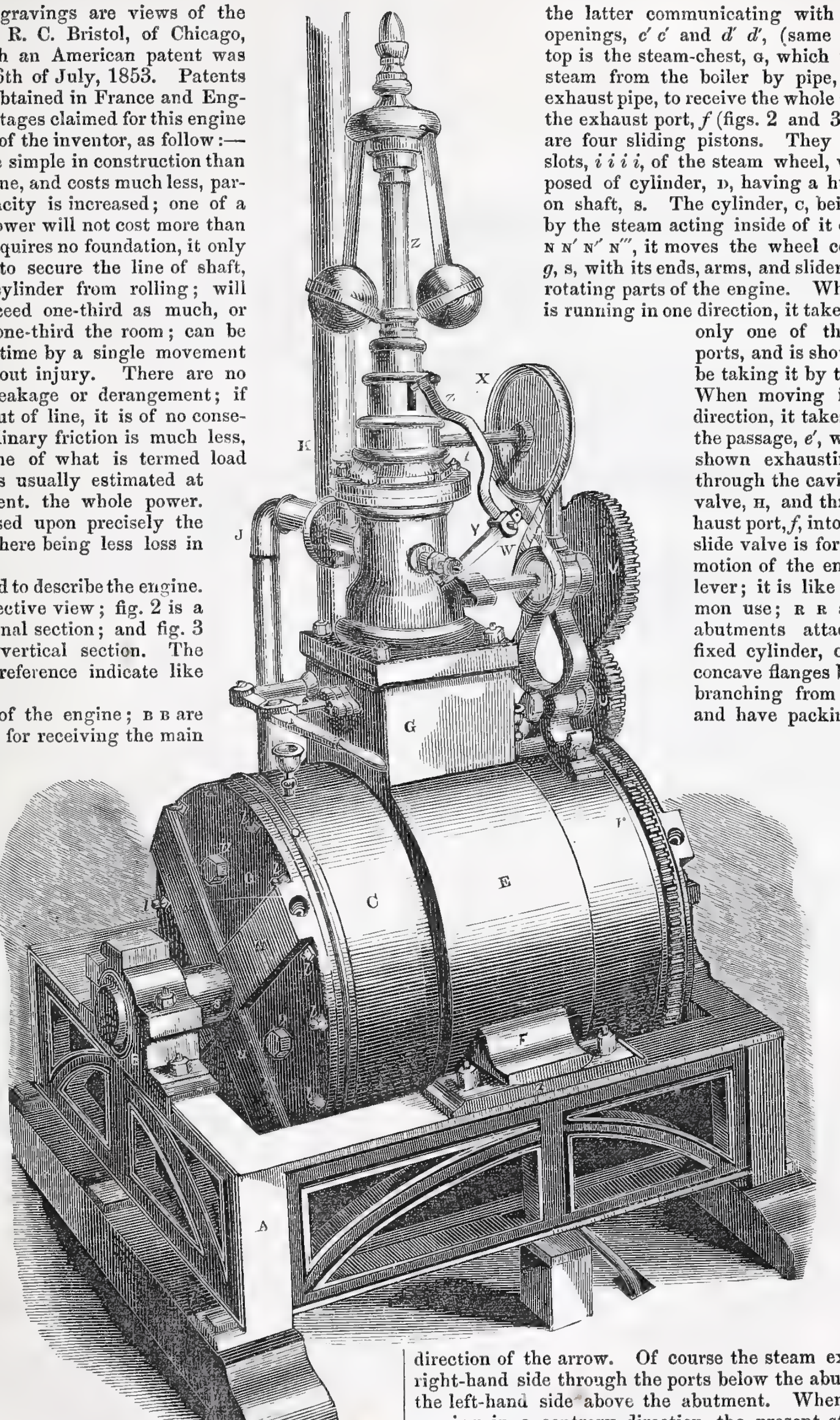
the return-pipe, and the water-space opposite the cock. Fig. 2 is a front view of the cock placed opposite the uppermost water-space, with the neighbouring parts of the pipes and the chest. Fig. 3 is a longitudinal section of the cock and a portion of the chest—*a* is the supply-pipe; *b*, the return-pipe; *c*, the chest; *d*, the cock, the aperture in which is seen in fig. 3; *e*, the lever for turning the cock; *f*, one of the bolts for binding together the sand and gravel beds; *u*, the uppermost water-space; *v*, the gravel-bed; *w*, the sand-bed. When the filter is in operation, the cock *d* connects the tube *a* with the upper side of the chest, and the bottom cock connects the end of the pipe *b b* with the under side; the intermediate cocks are at the same time turned off, disconnecting the chest with both of the pipes. Thus, as in the square filter, the unfiltered water is forced to descend through the entire height of the chest before it falls into the return-pipe. To cleanse the sand-beds, the process is similar to that for the square filter.

BOOTH'S PYROMETER.

This instrument is intended for measuring the degrees of heat in potter's furnaces, and is upon the same principle as the one invented by the late eminent porcelain manufacturer, Wedgwood, at whose death the method of making it was lost. The Pyrometers in use at the time of Wedgwood's original invention of this instrument, were imperfect in the extreme, and he experienced great difficulty in ascertaining correctly the heat of his porcelain furnaces. In order to remedy this inconvenience, he availed himself of the property which clay possesses, of contracting by heat, and remaining afterwards in that state of contraction when cold. The great difficulty to be overcome in producing a really useful Pyrometer upon this principle, will be understood when it is remembered that although all argillaceous substances do contract by the application of heat, yet they do not contract uniformly according to the degree of heat applied to them. By a peculiar preparation of the clay, Mr Wedgwood avoided this objection: he moulded the composition into cylindrical bars, and then ascertained their exact dimensions by observing the distance to which they sunk between two scales of metal inclined to each other at a small angle; after subjecting them to the heat of the furnace, the scale was again applied to them when cold, and in this manner the degree of heat to which they had been exposed, was indicated by the amount of their contraction. Wedgwood divided his scale into 240°; and in order to compare it with that of Fahrenheit's thermometer, he made use of a piece of fine silver, fitted to the same mould as the Pyrometric pieces of clay. Having determined the expansion of silver between 50° and 212° of Fahrenheit, the silver and clay were subjected to the same heat, and by a comparison of the expansion of the one with the contraction of the other, he estimated that each degree of his scale was equivalent to 130° of Fahrenheit's. A material improvement has since been made upon Wedgwood's instrument by Morveau. In a solid plate of highly polished porcelain, a groove is cut, containing a flat bar of platinum, an inch and three quarters in length, two tenths of an inch broad, and one tenth of an inch thick. One extremity of this bar abuts against the bottom of this groove, and the other is arranged so as to press against the short arm of a bent lever, the long arm of which, moving on a centre, indicates the degree of heat on a scale attached to the porcelain. Wedgwood's instrument, as reproduced by Mr. Booth, may be serviceable, in some instances, in the porcelain manufactories; though other instruments are more generally appliable to steam-engine and other furnaces.

BRISTOL'S ROTARY STEAM-ENGINE.

Fig. 1.



The annexed engravings are views of the rotary engine of R. C. Bristol, of Chicago, Illinois, for which an American patent was granted on the 26th of July, 1853. Patents have also been obtained in France and England. The advantages claimed for this engine are, in the words of the inventor, as follow:—"It is much more simple in construction than the common engine, and costs much less, particularly as capacity is increased; one of a hundred horse power will not cost more than 1500 dols. It requires no foundation, it only being necessary to secure the line of shaft, and block the cylinder from rolling; will not weigh to exceed one-third as much, or take more than one-third the room; can be reversed at any time by a single movement of the hand without injury. There are no parts liable to breakage or derangement; if the shaft gets out of line, it is of no consequence. The ordinary friction is much less, and there is none of what is termed load friction, which is usually estimated at about 14 per cent. the whole power. The steam is used upon precisely the same principle, there being less loss in space."

We now proceed to describe the engine. Fig. 1 is a perspective view; fig. 2 is a vertical longitudinal section; and fig. 3 is a transverse vertical section. The same letters of reference indicate like parts.

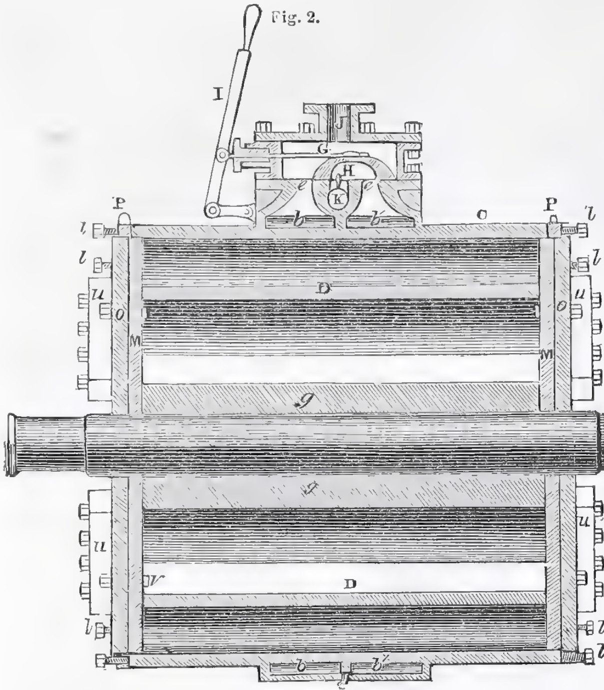
A is the frame of the engine; B B are the journal boxes for receiving the main shaft, S, to which the revolving part of the engine is secured; C is a cylinder; it is bored true, faced at the ends, and is surrounded by a steam-case, E, which is furnished with two lugs, F F; the lower faces of these lugs are slightly convex, and rest on suitable bearing plates, which are adjustable by set screws, to adapt it to the bearing surfaces of the shaft, S. The double steam-case, E, has passages, *b b* (fig. 2), both encircling the cylinder, but independent of each other; the former communicating with the interior of the cylinder through openings, *c c* and *d d* (fig. 2), and the latter communicating with the same by openings, *c′ c′* and *d′ d′*, (same fig.). On the top is the steam-chest, G, which is supplied by steam from the boiler by pipe, J. K is the exhaust pipe, to receive the whole steam through the exhaust port, *f* (figs. 2 and 3). N N′ N″ N‴ are four sliding pistons. They are set in the slots, *i i i i*, of the steam wheel, which is composed of cylinder, D, having a hub, *g*, secured on shaft, S. The cylinder, C, being stationary, by the steam acting inside of it on the sliders, N N′ N″ N‴, it moves the wheel composed of D, *g*, S, with its ends, arms, and sliders, forming the rotating parts of the engine. When the engine is running in one direction, it takes its steam by only one of the slide valve ports, and is shown in fig. 2 to be taking it by the passage, *e*. When moving in a contrary direction, it takes its steam by the passage, *e′*, where it is now shown exhausting the steam through the cavity of the slide valve, H, and through the exhaust port, *f*, into pipe, K. The slide valve is for reversing the motion of the engine; I is its lever; it is like those in common use; R R are two fixed abutments attached to the fixed cylinder, C; these have concave flanges between them branching from their apexes, and have packing bars, *m m*, which are adjusted by screws, *p p*, to press steam-tight against the rotary cylinder.

The steam is now shown as being let in through the ports, *c′ c′*, on both sides of the engine, the one at the right-hand side, fig. 3, on the upper side of the abutment, and at the other side beneath the abutment, making the engine rotate in the direction of the arrow. Of course the steam exhausts at the right-hand side through the ports below the abutment, and on the left-hand side above the abutment. When the engine is moving in a contrary direction, the present steam passages become the exhaust passages.

The sliders, N N′ N″ N‴, by this arrangement of the steam and exhaust ports, are relieved of all steam pressure when passing the abutments, so that there is very little friction on

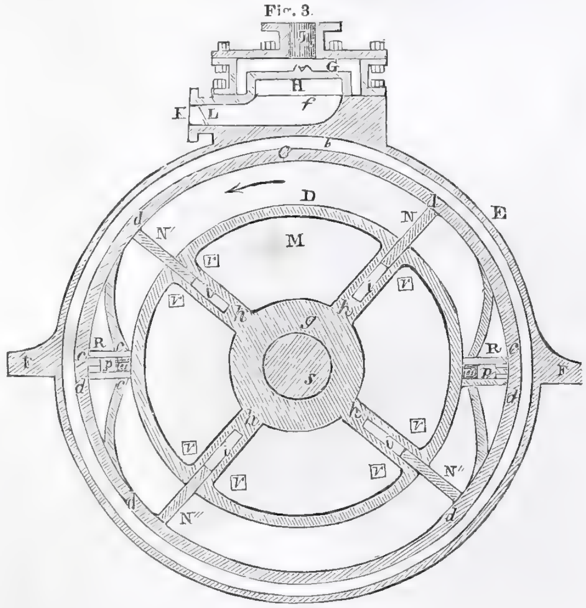
them. In other rotary engines with abutments, the sliders are forced out by a heart, or similar cam, but these sliders are forced out by steam pressure acting on small pistons in the

Fig. 2.



chambers, *u u u u*, in both ends of the engine. The ends of the sliders have projections outside of the ends of D; these are connected to small pistons in the chamber, *u u*, which small pistons are actuated by steam in the chambers at the ends of the cylinder. The steam from the small pistons is exhausted

Fig. 3.



before a slider comes to an abutment, but commences to act to press out the slider when it passes an abutment. These sliders work free in their recesses, *i i*, in the arms, *h h*, but are always pressed steam-tight, and allow no steam to pass them.

M M are the inside cylinder heads, in which there are slots for the projections of the sliders, to be actuated by the small steam pistons mentioned before. O O are other cylinder heads, secured by bolts, *v v*, and fitting close to M M, but have flanges, P P, all around the outer side; Q Q are stiff metal packing rings, corresponding with the size of the interior of the outer cylinder, and fitting closely over the inner heads, M M. These packing rings are pressed up by the screws, *l l*, passing into the flanges, P P. There is a rotary expansion valve in the chamber above G, which may be made to cut off the steam at any desired point; it is rotated by wheels, U V, which are operated by the revolving cylinder, one of the heads being formed with teeth on its periphery. The governor is operated by a cord passing from the small pulley, W, over X, which rotates its spindle and that of the governor; the sliding sleeve, 2, of the balls, operates the throttle valve through the angle arm, Z Y, in the usual way. The moving joints are all made upon the principle, that two smooth metal surfaces make a steam joint without pressure or weight, and, consequently, without friction.

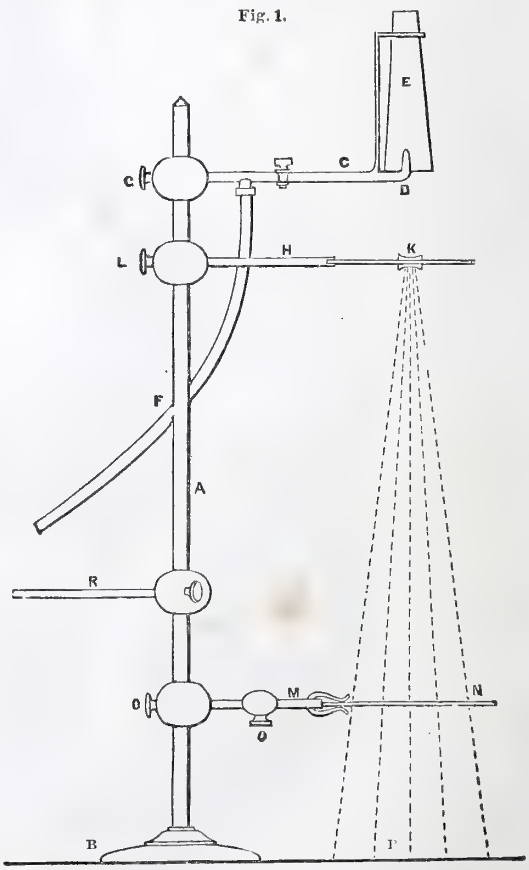
By this description, and these illustrations, a proper idea of the principle and operation of this rotary engine will be obtained. Its advantages, as pointed out, when compared with others, says the inventor, will show how free it is from lateral friction. This engine was on exhibition at the Crystal Palace, New York.

INSTRUMENT FOR ENLARGING AND REDUCING PATTERNS AND DESIGNS.

THIS instrument, invented by Mr. Thomas Macdonald, Glasgow, is designed to assist in enlarging and reducing drawings by a readier process than that afforded by the pentagraph. It is constructed on simple optical principles, and though its range of operation is limited, it is capable of numerous useful applications.

Description.—Fig. 1 represents this instrument in the state in which

Fig. 1.

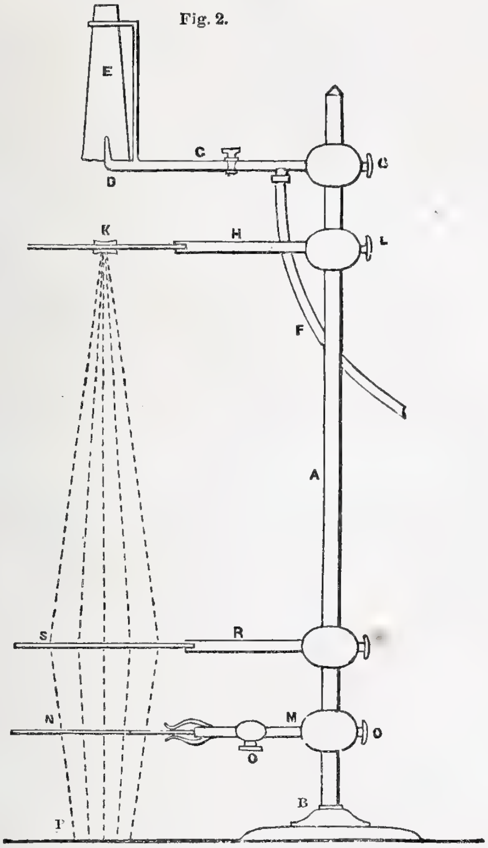


it is when employed to enlarge a pattern or design; fig. 2 the same, when adjusted to produce copies on a reduced scale.

A is a pillar, four feet, more or less, high, with a broad basement, B; C, a hollow sliding arm, which terminates at its outer extremity

in a gas-burner, D (or other artificial light), surrounded by a conical glass chimney, E. The taper of the chimney is given to it with the view of enabling the flame to burn steadily. F is a flexible tube, by which gas is supplied to the hollow arm, C. G is a binding screw, by which the arm, C, and, of course, the light, can be fixed at any height required. H is a second sliding arm, which supports at its outer extremity a concave lens, K, and may also, by means of the binding screw, L, attached to it, be fixed at any required height. M is a third sliding arm, which terminates at its outer extremity in a strong clasp, in which is inserted a glass plate, N, on which is drawn, in some opaque colour, the pattern or design which is to be enlarged (the drawing having been made by superimposing the glass on the original pattern, and then tracing it out upon it). O O are two bind-

Fig. 2.



ing screws, one for securing the arm, M, and the other the plate, N, in its place. P is a piece of card or paper, on which the pattern or design on the plate, N, is produced in shadow on an enlarged scale. R is a fourth sliding arm, exactly similar to H, but carrying at its extremity a convex lens, S, by the interposition of which between the pattern plate, N, and the lens, K, the rays of light are concentrated, and the copy in shadow produced of a smaller size than the original. When the pattern or design is to be enlarged, the arm, R, is turned round out of the way, as shown in fig. 1.

The pattern or design is enlarged, more or less, according to the nearness of the pattern plate, N, to the light; and in like manner the outline on the pattern plate is more or less diminished, according as the convex glass, S, is raised or lowered.

The shadow of the pattern or design is also more or less foreshortened, as the pattern glass, N, is turned more or less at an angle to the paper which the shadow is thrown down upon.

TEMPERING APPARATUS, PARTICULARLY APPLICABLE TO THE TIRES OF WAGGON AND LOCOMOTIVE WHEELS.

By M. Coutant, Foundry Manager, at Ivry, near Paris.

M. Coutant, who has given much attention to metallurgy, and particularly to the tempering of iron, deemed it very important for railway companies to be able to temper the wheel-tires of railway carriages, tenders, and locomotives, so as to give to their exterior surface greater hardness, and render them, consequently, more durable.

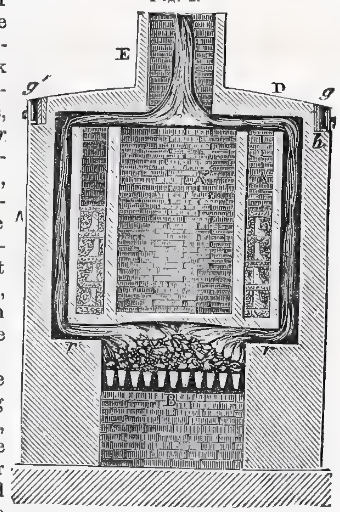
But as the methods of hardening iron hitherto employed did not appear to him sufficient to attain this object, he has tried to construct a simple and convenient apparatus, in which he might, at one operation, temper a certain number of tires to the same degree, and with the most perfect regularity, exempting from the action those parts of the tire not intended to be hardened.

His system consists of a cylindrical furnace, constructed of brick, with a central and circular grate, over which is placed a double-walled receiver, also cylindrical, between the walls of which the tires to be hardened are introduced.

Fig. 1 is a vertical section made through the centre of the apparatus, and fig. 2 a horizontal section over the fire-grate.

It is easy to perceive by these figures that the exterior mass of the furnace, properly speaking, is simply a cylinder of brick, A, enclosing a kind of double-walled vessel or holder, A^1 and A^2. The bottom, of the same material, that is to say, of brick or fire-clay, is placed directly over the grate, B, and rests on the ledges, r and r', formed in the structure, as shown in the plan, fig. 2, and leaving openings, which allow the flame and smoke to circulate in the open space left around the exterior wall, A^1, to its upper part, when they escape into the chimney.

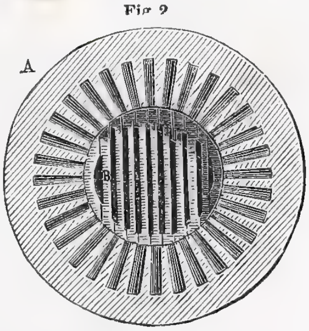
Fig. 1.



Fuel is supplied to the grate by the opening in front of the furnace, and draught-holes are made towards the upper part, which can be stopped up at pleasure, and serve for inspecting the interior, to see if the flame is quite bright, and if the receiver has arrived at the temperature suitable for tempering the metal. These loop-holes may be multiplied at pleasure, and stopped with plugs or bricks.

On the top of the furnace is applied the moveable lid, D, in the centre of which is a vent, E, communicating with the general chimney. To the exterior circumference of this lid are fitted several rollers or grooved wheels, g and g', which allow of its running on the iron rails, h, h', to uncover the furnace, and by which it is again restored to its former position.

Fig. 2.

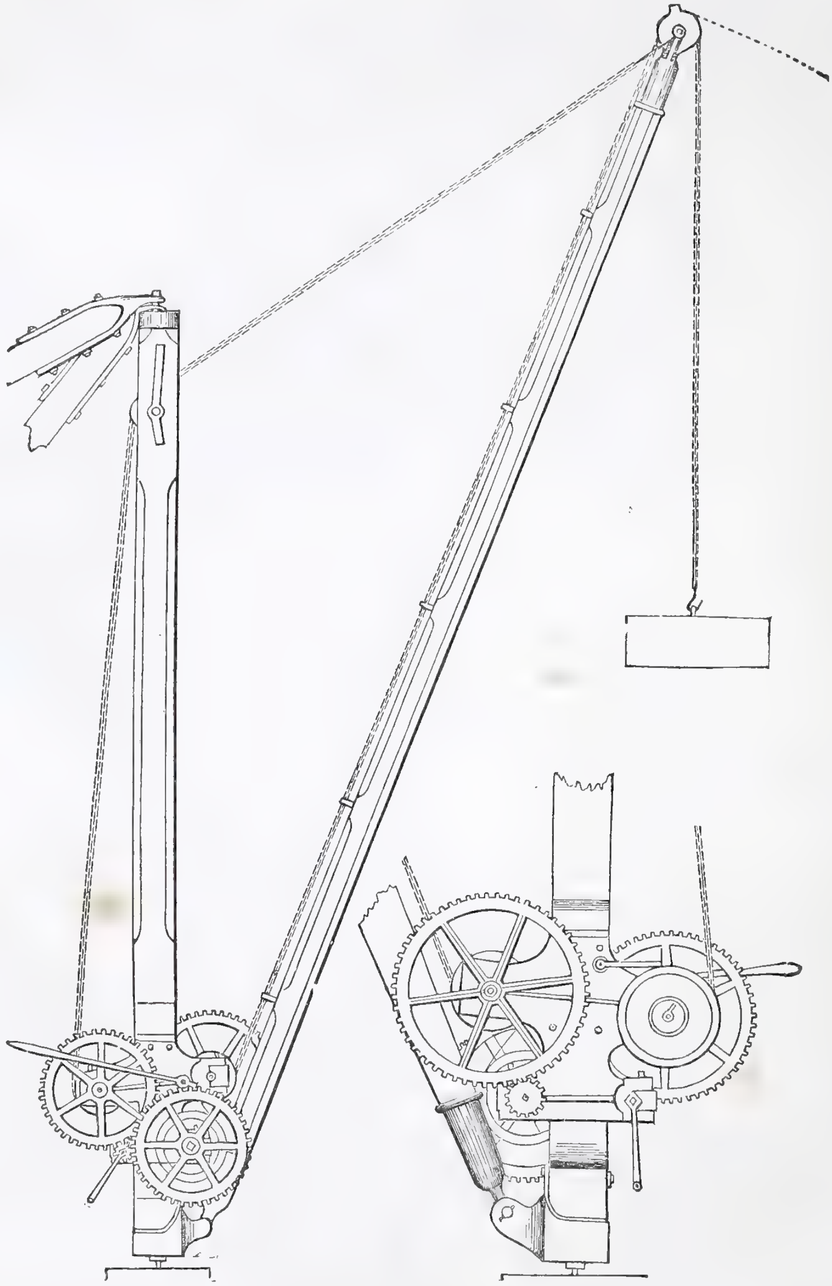


The tires to be hardened are placed horizontally in the empty space between the two walls, A^1 and A^2, of the receiver; these tires are introduced successively with powdered charcoal, which is put only in contact with the outer circumference, so as to harden only that part; the inner circumference, towards the wall, A^2, is protected in the first place by this wall itself, and may be further protected by the addition of earth. It is the exterior wall, A^1, of the receiver, in which the entire action of the heat is brought to bear, and which is heated in consequence until it attains the temperature deemed sufficient for the purpose.

By this arrangement of furnace, M. Coutant is enabled to harden the exterior surface of wheel-tires, and thus to temper them to the degree required, while leaving, at the same time, the internal part possessed of its natural malleability. It is affirmed that, with this arrangement, the best results are obtained.

THE MOVEABLE DERRICK CRANE.

A DERRICK crane, constructed by Messrs. Fox, Henderson, and Co., London Works, Birmingham, was one of the "machines for direct use" which figured in Class V. of the Great Exhibition of Industry in 1851, and was, on that memorable occasion, put into "direct use," or actual service, in lifting the heavy machinery around it into their places, as well as in their subsequent removal when the Exhibition



came to a close. It was likewise employed in the construction of the building, and particularly in unloading and testing the cast-iron girders or framework.

The annexed figures are a representation, not of the crane which was exhibited by Messrs. Fox, Henderson, and Co., but of one of the first which was constructed on the same principle; and the following remarks on the subject by Mr. William Wightman, who may be regarded as the inventor of the modern crane, with its most important improvements, are extracted from a paper which was read by that gentleman before the Society of Arts, in Edinburgh. The paper has both an historical and practical interest.

"It is well known," says Mr. Wightman, "that previous to the year 1837, no other crane was generally known or used in the construction of public works, but the common, or what might be appro-

RECIPROCATING & PENDULOUS ENGINES

MANCHESTER

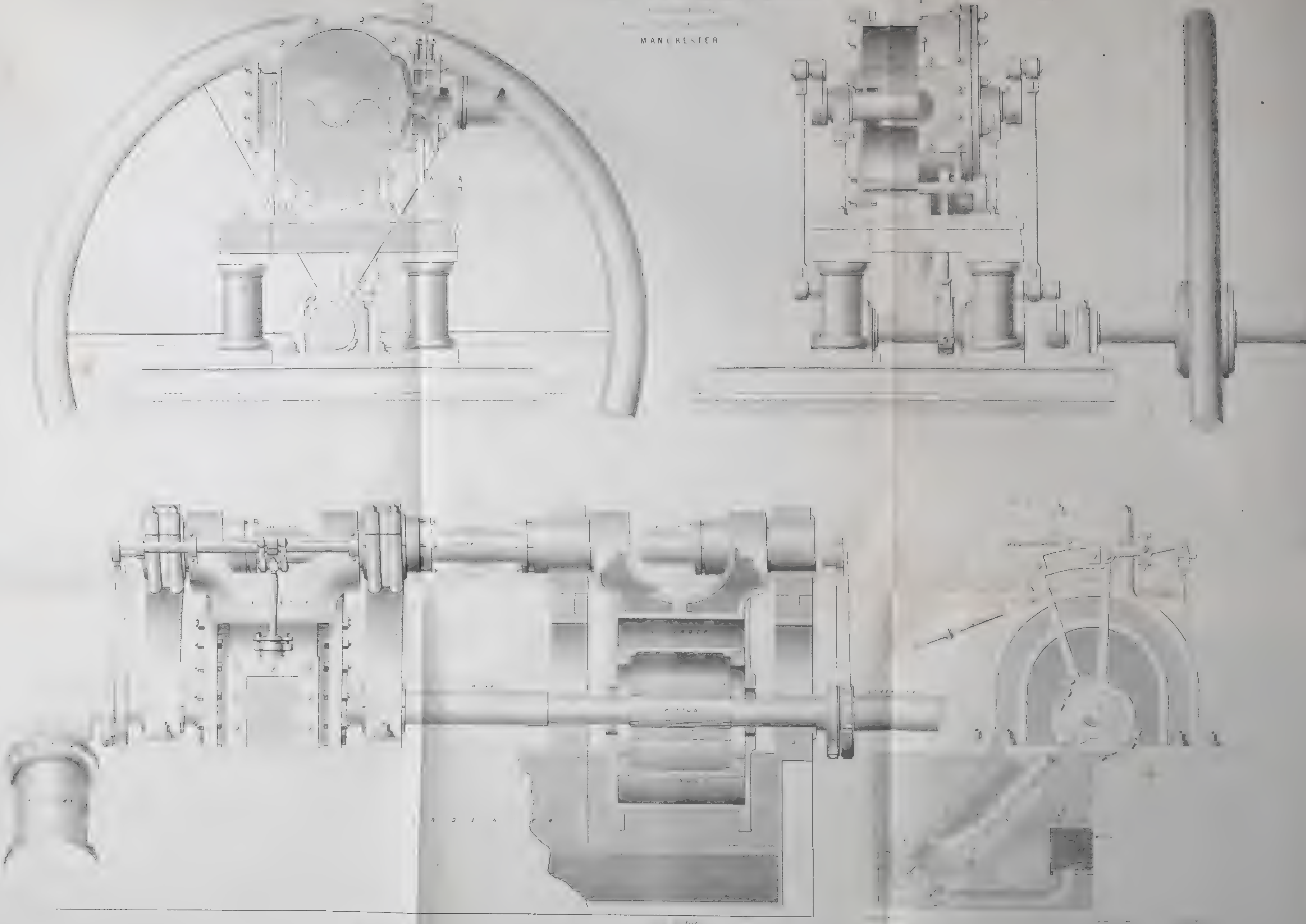
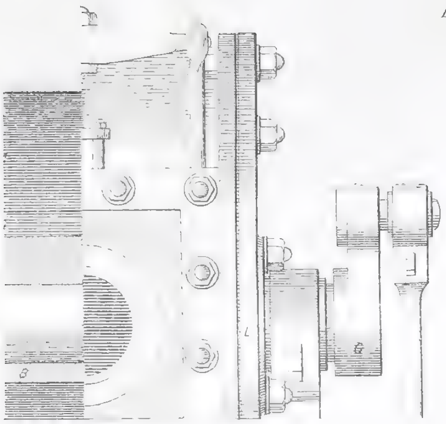


Fig. 2.



priately called, the gibbet crane. These differed sometimes a little in the form and arrangement of their machinery, but never so much as to alter their principle. They were, however, even in their most approved form, always unwieldy, top-heavy, and difficult and dangerous in fixing up or taking down; so much so, that more accidents occurred from these frequent operations, than from performing their proper work. It will also be easily observed, that their capabilities for lifting or depositing stone or other material in the construction of works soon became exhausted, from the point of suspension being immoveable to or from the fulcrum, and performing only one circle of a radius equal to the length of the cross-beam.

"This great defect could, in some measure, be remedied a little, by applying a tackle fall to the material in suspension, and dragging it by main force from the perpendicular to the place required, or as near to it as could possibly be effected.

"From this and the other defects, it will be admitted, that the gibbet crane was a very imperfect machine for lifting and conveying heavy masses of building or other material, to or from their ever-varying positions; and required to be taken down and removed, in most cases every other day, thereby incurring great expense and loss of time.

"On entering with my partners into the contract with his Grace the Duke of Buccleuch for the erection of Granton Pier, the deficiency of the common crane called my attention to various schemes for a remedy, which at last resulted in the construction of the Improved Moveable Derrick Crane, represented in the annexed figures.

"It may be proper, however, here to state, that, although I never had then either seen or heard of anything of the kind, a crane having a moveable jib, but with very different and more complicated machinery than mine, was used by Mr. Stevenson at the Bell-Rock Lighthouse, upwards of thirty years before; the defects of which, as well as the improvements effected by me, were very clearly pointed out in a paper read before the Society some time since, by Mr. James Slight, F.R.S.S.A., engineer, Edinburgh, containing an exposition of the strains to which cranes on various forms are subject; for which the honorary medal was awarded to him.

"I am sorry to occupy the time of the Society with a mere detail of circumstances; but I wish to state, as a proof of the extent of existing prejudices against the introduction of many useful improvements, that, after I had, at a great expense, got my first crane built, I consulted with a gentleman of considerable mechanical knowledge and experience as an engineer, who, after examining it, strongly advised me to break it up, without even a trial; and, from my confidence in his opinion, it was put aside a whole month, before I ventured to put it up for trial.

"Its decided superiority, easy management, and its capacity for forming an almost infinite variety of concentric circles (so much required in extensive building operations), were, in a short time, so manifest, that I had applications from several most respectable builders to be allowed the use of the patterns for sets of castings. From this period, my improved crane began gradually to come into general use; and I may be permitted to state, that the most of the bridges and viaducts on the Edinburgh and Glasgow Railway were built by its means. I have seen it most successfully applied to shipbuilding, the derrick being no less than 70 feet in length, and capable of placing a heavy timber plank on any part of a large ship, besides commanding an extensive range of the yard for picking up timber.

"The figure is intended to represent the improved moveable derrick crane in its full proportions, as generally used; but as the mast and derrick may be increased or diminished to suit circumstances, there can be no fixed rule for the length of either. I have never used any mast less than 25 feet, or any derrick more than 55 feet; and where they are used for any purposes which require them to be frequently removed, I would recommend that the length of the derrick should not exceed 40 feet (unless the nature of the work requires it), and that the derrick should never be lowered to a greater angle from the mast than 65 degrees, as the strain upon the derrick chain and the stays of the mast, even at that angle, becomes very great.

"The chain for raising or lowering the derrick is usually of the best cable iron, three quarters and one-sixteenth of an inch diameter; and the purchase or lifting chain of the same iron, but eleven-sixteenths of an inch in diameter. With these, if judiciously stayed, the crane will lift or deposit, anywhere within its range, a weight of 4 tons. One thing ought to be particularly attended to,—never to allow any workman to guide or shift the machinery without having been trained a little to its management; as the most trifling error, such as neglecting to let down the click of the ratchet-wheel, when throwing out of gearing the handles, after lowering the derrick, might be productive of serious consequences; while, on the other hand, with a little experience and attention, nothing can be more safe.

"The small figure exhibits the reverse side of the crane, but on a little larger scale."

MESSRS. SIMPSON AND SHIPTON'S SHORT-STROKE RECIPROCATING STEAM-ENGINE.

This engine was patented by the inventors, Messrs. Joseph Simpson and James Shipton, in the year 1848, and, although called by them a "reciprocating engine," comes more properly under the denomination of a rotary engine. It really combines the two motions, but is more closely allied to the latter class of engine, for the piston, or prime mover, rotates upon its axis. The engine will no doubt be remembered, by many of our mechanical readers, as having been applied to drive a series of the manufacturing machines, exhibited in that portion of the Great Industrial Exhibition of 1851, devoted to the manufacture of textile fabrics.

It is, perhaps, one of the most ingeniously contrived of all the rotary engines which have been devised, and is decidedly one of the best in its practical results.

In the plate and cuts we have given of this engine, figs. 1—4 show two distinct modifications of the invention: in the first of which the main shaft, or axis, of the revolving piston vibrates; and, in the second, this shaft revolves in fixed bearings, and may therefore be the main driving shaft of the engine, or the screw shaft when the engine is applied for the purpose of driving the marine screw propeller.

Fig. 1 is a side view in section, and fig. 2 an end view, partly in elevation and partly in section. The letters of reference denote the same parts in both figures.

A is a steam chamber, supplying the place of the ordinary cylinder; this chamber is in horizontal section rectangular, the top and bottom being closed with hemispherical ends, as seen in fig. 1. B is the piston, keyed eccentrically to the shaft or axis, C. The piston is in form a cylinder, the curved surface of the cylinder rubbing steam-tight against the two flat plates, D and E, forming two sides of the steam chamber; the ends of the cylinder are fitted with packing rings, which rub steam-tight against the other two flat sides, L L, of the steam chamber. The two hemispherical ends of the steam chamber may be left as they are cast, as they never come in contact with the piston, being, in fact, equivalent to the top and bottom of the ordinary cylinder. The plate, E, is stationary, but the opposite plate, D, is pressed up by springs, to compensate for wear in the rubbing surfaces. It will be evident from the foregoing, that, if steam be admitted within the chamber, A, and alternately above and below the piston, it will rotate upon its axis, C, but this axis must, at the same time, be allowed to vibrate, as explained by the following diagrams, in which the piston is shown at different parts of its stroke; when it is either at the top or bottom of the stroke, its axis will be in the centre of the steam chamber, as represented at fig. 5; when at the left-hand half-stroke, fig. 6, the axis will have passed to the point, a; and when at the opposite, or up half-stroke, fig. 7, the axis will be at a'; the axis thus vibrates (during the piston's rotation) alternately from a to a'. To allow of this play, an elliptical opening, b, is left in each cover to the steam chamber; see fig. 8. The action of the piston being thus far explained, it only remains to describe the method of imparting the combined motion of the piston to a shaft revolving in fixed bearings. The piston-shaft, C, is supported at each end by the rods, F F, radiating from the crank-shaft, S, supported on gudgeons forming part of the crank-shaft pedestals. The radius bars, F F, vibrate with the piston. Upon the extreme ends of the piston-shaft (outside the supporting radius bars, F) are keyed the cranks, G G, which transmit the rotatory motion of the piston through the connecting side-rods, H H, to the main cranks, I I, upon the driving-shaft, S.

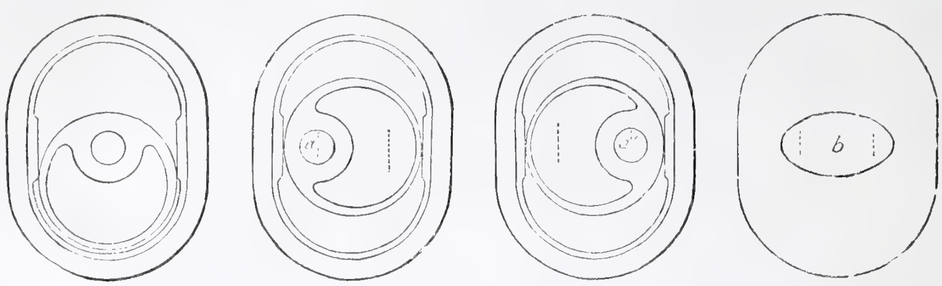
The elliptical openings, b, left in the chamber covers, to allow of the vibration of the piston-shaft, are made sufficiently large to enable them to be passed over the cranks, and they are of great practical utility in giving ready access to the interior of the piston, to screw up the packing rings. These rings are fitted differently to the rings used with the common piston, which are pressed out radially. In this engine the

rings are wedge-shaped, and pressed out against the flat ends of the steam chamber, at right angles to the piston's periphery. The rotatory action of the piston causes the rings to slide round in their seats, which, combined with its eccentric action, beautifully equalizes the wear of the rings. The remaining details of the engine do not differ in any way from those applied to the ordinary reciprocating engine, and, consequently, need no special description.

A modification of this invention—shown upon the plate, at figs. 3 and 4—has been arranged for driving the screw propeller, in which many of the working parts described in the former engine are dispensed with.

This is effected by placing the piston-shaft in fixed bearings, and suspending the steam chamber upon hollow trunnions, to allow of the eccentricity of the piston's rotation, in which form it much resembles the ordinary oscillating cylinder. The steam enters from the boilers through the steam-pipe, *m*, which forms the support to the one side of the steam chambers,

Fig. 5 Fig. 6. Fig. 7. Fig. 8.



c, and passing through channels cast upon the steam chambers, enters the valve-chest, *e*. The exhaust steam passes off through similar channels into the exhaust pipes, *o*, which form the support to the opposite sides of the steam chambers. The piston-shaft, *a*, here serves as the screw-propeller shaft. The two air-pumps lie at right angles to each other, and at an angle of 45° to the propeller shaft, and are both worked from one crank-pin by the crank, *i*. *p p* are the eccentrics for working the quadrants, *r*, by means of which the valve gear is actuated. *s* is the reversing lever.

With regard to the cost of working this engine, compared with the ordinary cylinder engine, it is stated by the inventors that an experimental trial was made at Messrs. Ellis & Co.'s works, at Salford, between this and a common engine of good make and condition. The work was that of a large fan, for foundry purposes; the engines were attached to the same boiler, and fired from the same heap of coals. In the common engine, the coal burnt was 1 ton 7 cwt. 1 qr., and the quantity of metal melted, 16 tons 14 cwt. In the patent engine, the coal burnt was also 1 ton 7 cwt. 1 qr., and the quantity of metal melted, 18 tons 9 cwt. 2 qrs., thus giving 12·25 lbs. of metal to 1 lb. of coal in the common engine, and 13·56 lbs. of metal to 1 lb. of coal in the patent engine.

It is much to be regretted that inventors do not make it a more general rule to try their engines by a dynamometer, and, at the same time, take indicator cards, for it is only by ascertaining the actual indicated horse power, and the power given off upon the dynamometer, that the power absorbed by the engine by leakage and the friction of its working parts, or, in other words, that the economy or otherwise of any particular form of engine, can be ascertained.

For the purpose of driving the screw propeller, this engine seems well adapted, as it occupies but little space, and lies low down in the vessel; and the economy of steam depends more upon the furnaces and boilers, and efficient firing, than upon the mechanical arrangement of the moving parts of the engine. There appears to be no reason to fear more accidents in derangement of this engine than in any other, for the moving parts are few in number, and every portion of the engine easily got at for repairs.

HORTICULTURE.

CHAPTER XI.

FLORIST'S FLOWERS.

Some flowers have been most particularly attended to, and are called florist's flowers. These are the hyacinth, the tulip, the ranunculus, the anemone, the dahlia, the auricula, the carnation, and the pink. Other plants are sometimes considered to belong to this division, but we shall content ourselves with some general remarks upon each of the above.

THE HYACINTH.

The hyacinth is a native of the Levant, where it flowers in February. Here it flowers in March and April, and is one of the most beautiful of our spring flowers. It was brought to its present state of perfection by the Dutch, in the beginning of the last century.

A great number of varieties of the hyacinth exist. They may be arranged under the heads of single, semi-double, and double. Under each of these sections, are members of great varieties of tints. The following is Smith's definition of a fine flower: "The stalk should be tall, strong, and upright; the blossoms numerous, large, and suspended in a horizontal direction; the whole flower having a compact pyramidal form, with the uppermost blossoms quite erect; plain colours should be clear and bright, and strong colours are preferable to pale; when colours are mixed, they should blend with elegance."

A rich but light and sandy soil is necessary for the hyacinth. New varieties are obtained by means of seeds, but the ordinary method of perpetuating obtained varieties is by offset bulbs. Hyacinth bulbs are planted towards the end of October; they are placed three or four inches deep in the ground, and many cultivators put sand above and below them. The bulbs during winter are protected from the frost, either by placing litter or awnings over the ground above them.

Most of the hyacinths grown in this country, are obtained from bulbs that are imported from Holland.

THE TULIP.

The tulip is a native of the East, and was introduced from thence, in the sixteenth century, into this country. The flower of the tulip, notwithstanding its gaudy appearance, is not a corolla proper, but a calyx. About two centuries ago, the cultivation of the tulip, under the name of the Tulipomania, was very absurdly carried on in Holland. It is said that £460 in money, a carriage, a pair of horses, and the accompanying harness, were paid for one bulb. Another individual gave, in exchange for a single root, twelve acres of land. The rage for tulip-growing spread to England, where, however, it soon received a check, and perhaps the tulip is now scarcely duly appreciated.

There are, we should observe, a number of tulips, as the yellow, red, double Claremont, &c., which are despised by the florist, although generally grown by the ordinary gardener. The florist's tulips are arranged in four classes. These are:—

1st. The Bizarre, the members of which are characterized by having a yellow ground, marked with purple or scarlet.

2d. The Byblœmons, members of which have a white ground, marked with violet or purple.

3d. The Roses, the members of which have a white ground, marked with rose-colour.

4th. The Self or Plain-coloured, the members of which are of one uniform colour.

The following is a definition of a good tulip: "The stem should be strong, erect, thirty inches high; the flower large, of six sepals, which should proceed almost horizontally at first, and, turning up, should form an almost perfect cup with a round bottom, rather widest at top. The three exterior petals should be rather larger than the three interior ones; the limbs of the petals should be rounded and free from every species of serrature. The ground colour of the flower at the bottom should be clear white or clear yellow, and the various rich-coloured stripes, which are the principal ornament of a fine tulip, should be regular, bold, and distinct at the margin, and terminate in fine broken points, elegantly feathered and pencilled. There are other refinements upon which florists are not quite agreed, and it must be confessed that their standard of excellence is somewhat fastidious, for, to an uninstructed eye, though practised in the contemplation of other sorts of beauty, a tulip, which by them is looked upon as worthless, will often appear as fine as the choicest variety in the select bed."

The tulip is propagated by seed in order to obtain new varieties, but in the ordinary manner by bulbs. The soil that is thought most suitable for them is a light turfy one, but well manured. The manure is mixed with the earth about the middle of October, and a fortnight after this operation the bulbs are planted. They are usually placed in rows about eight inches apart, and buried three inches deep, often with a little sand around them. The tulip bed, like that of the hyacinths, should be protected from the frosts of winter. In spring, too, the young plants must be protected from night frost and from heavy rains; and in summer, the flowers must be screened from the rays of a hot sun, which are very injurious to them. When the flower fades, the seed vessels must be broken off by the stems, in order that the whole form of the plant may be directed into forming the new bulb. When the leaves have withered, the bulbs are lifted and stored until the end of October.

THE RANUNCULUS.

This also is an Eastern plant, but as a florist's flower it is essentially English. Innumerable varieties, or supposed varieties, have been described. We extract the following as a definition of a good double ranunculus:—"The stem should be strong, straight, and from eight to twelve inches high, supporting a large well-formed blossom or corolla at least two inches in diameter, consisting of numerous petals, the largest at the outside, and gradually diminishing in size as they approach the centre of the flower, which should be well filled up with them. The blossom should be of hemispherical form; its compound petals should be intricated in such a manner as neither to be too close or compact, nor too widely separated, but have rather more of a perpendicular than horizontal direction, to display their colours with better effect. The petals should be broad, and have perfectly entire well-rounded edges; their colours should be dark, clear, rich, or brilliant, either consisting of one colour throughout, or be otherwise variously diversified on an ash-white sulphur or fine coloured ground, or regularly striped, spotted, or mottled, in an elegant manner."

In order to obtain new varieties, the ranunculus is propagated by seeds, but the ordinary mode is by offshoots from bulbs. Ranunculus cultivators like a strong and moist soil. Mr. Williamson used a stiff clay, with one-fourth part of rotten dung: "The bed," he says, "should be dug from eighteen inches to two feet deep, and not raised more than four inches above the level of the walks, to preserve the moisture more effectually. At about five inches below the surface should be placed a stratum of two years' old rotten cow-dung, mixed with earth six or eight inches thick; but the earth above this stratum, where the roots are to be planted, should be perfectly free from dung, which would prove injurious rather than of benefit if too near them. The fibres will draw sufficient nourishment from it at the depth above mentioned; but if the dung was placed deeper, it would not receive so much advantage from the action of the air, which is of consequence."

Not being personally much versed in the cultivation of florist's flowers, we will take the liberty to extract the same author's directions regarding planting ranunculuses.

"This may be done," he writes, "either before or after winter. If the seed and situation are remarkably cold and wet, it will be better to defer planting till the middle or end of January, or the beginning of February, as the weather may favour; but in other situations, the latter end of October, or the beginning of November, is to be preferred, as the roots will have more time to vegetate and form themselves, and will in consequence bloom rather stronger, though only a few days earlier than those later planted. A bed, consisting of the variety called scarlet turbaned ranunculus, will produce a most brilliant effect; if planted at the same time as the tulip bed, they will bloom together; they are hardier than any other ranunculus, but may in other respects be treated in the same manner. The surface of the bed should be raked perfectly even and flat, and the roots planted in rows at the distance of about five inches from one another. It is better to plant in shallow trenches, made nearly two inches deep, than to make holes for the reception of the roots; there should be a little clean coarse sand sprinkled into the trench, and the roots should be placed with their claws downward, from three to four inches asunder, according to their size. When the trench has received its roots, it should be carefully filled up level with the same earth that was taken out, so as to cover the root exactly one inch and a half deep, which is the only true depth to procure a good bloom. It is pointed out by nature in a singular manner, for when these roots have been planted too shallow or too deep, in either case a second root is formed at the proper depth, by which the plant is weakened to such a degree, that it seldom survives a repetition of it."

Ranunculuses are planted so close in order that the foliage may cover the surface of the bed, and thus procure shade and moisture. The autumn-planted flowers require protection from the frost, and all kinds from the sun in summer. When the leaves wither, the roots must be taken up and stored.

THE ANEMONE.

Two kinds of anemone are cultivated as florist's flowers—the anemone coronaria, or poppy anemone, a native of the Levant, and the anemone hortensis, a native of Italy. All the florist's varieties of the anemone may be referred to the two classes of single and double blossoming. The criterion of a good double anemone is as follows:—"The stem should be strong and erect, not less than nine inches high. The blossom or corolla should be at least two inches and a half in diameter, consisting of an exterior row of large, substantial, well-rounded petals or guard-leaves, at first horizontally extended, and then turning a little upwards, so as to form a broad shallow cup, the interior part of which should contain a large number of small long petals intricating each other, and rather reverting from the centre of the blossom; there are a great number of small slender stamens intermixed with these petals, but they are short and not easily discernible. The colour should be clear and distinct when diversified in the same flower, or brilliant and striking if it consist only of one colour, as blue, crimson, scarlet, &c.; in which case, the bottom of the broad exterior petals is generally white; but the beauty and contrast is considerably increased, when both the exterior and interior petals are regularly marked with alternate blue and white, or pink and white, &c., stripes, which in the broad petals should not extend quite to the margin.

The culture of the anemone is the same as that of the ranunculus.

THE DAHLIA.

This plant is a native of Mexico. It found its way into this country during the latter half of last century, but was subsequently lost. It was restored by Lady Holland in 1804, and has now become a very great favourite, to which the time of its flowering (autumn) has no doubt partly contributed.

There are innumerable varieties of the dahlia. They may all be arranged in the three following divisions (Smith):—

1st. The common or camellia form.

2d. The anemone-flowered, the members of which have a radius of large petals, and a central disk of smaller ones.

3d. The globe-flowered, the members of which have small, very double globular flowers.

The following is Loudon's criterion of a good dahlia:—"The plant short, stiff, and bushy; prolific in flowers; having short peduncles; the flower well expanded, and standing boldly to the view, and the colours clear and distinct."

New varieties of the dahlia are obtained from seeds, but the common mode of propagating it is by parting the roots—(the dahlia, we should state, was first introduced on account of its roots, which are edible)—taking care that the parted piece has an eye in it.

Dahlias do best in good rich soil, and in an open situation.

The roots should be planted out early in May, and as the plants grow up, they should be furnished with strong stakes, to which they should be tied. After the first indication of frost in autumn, the roots must be taken up, dried, and stowed away in some place that is dry, and where frost cannot reach them.

Old roots, we may mention, sometimes throw up too many stems. Such should be thinned.

THE CARNATION.

Three varieties of this beautiful plant are cultivated. These are:—

1st. The flakes, the flowers of which have two colours, with their stripes running through and along the petals.

2d. The bizarres, the flowers of which are irregularly spotted and striped, with not less than three colours.

3d. The picotees, the flowers of which are spotted, and the petals serrated or fringed.

Of these three varieties, Mr. Hogg, who is the standard author upon the cultivation of the carnation as a florist's flower, has or had in cultivation between three and four hundred sub-varieties. Mr. Hogg's character of a fine double carnation is as follows:—"The stem should be strong, tall, and straight, not less than thirty, nor more than forty-five inches high; the foot-stalks supporting the flowers should be strong, elastic, and of a proportionate length. The flower or corolla should be of at least three inches in diameter, consisting of a great number of large well-formed petals, but neither so many as to give it too full and crowded an appearance, nor so few as to make it appear too thin and empty. The petals should be broad, long, and substantial, particularly those of the lower or outer circle, commonly called the guard-leaves; these should rise perpendicularly about half an inch above the calyx, and then turn off gracefully in a horizontal direction, supporting the interior petals, and altogether forming a convex, and nearly hemispherical corolla. The interior petals should rather decrease in size as they approach the centre of the flower, which should be well filled with them. The petals should be regularly disposed alike on every side, intricating each other in such a manner as that both their respective and united beauties may captivate the eye at the same instant; they should be nearly flat," &c.

The most usual mode of propagating carnation is by layers. These layers are made when the plant is in full bloom. Shoots for the purpose are selected; a few of the lower leaves are removed; an incision is then made below a joint. This incision must pass up to the joint, but not through it. The incised shoot is then pegged down, and covered with soil. In about a month, the incised part will have sent out roots, and become able to maintain a separate existence.

Many very minute directions are laid down as to the management of the carnation. Those interested in the subject will find them in full detail in the work of Hogg upon the subject. Very beautiful flowers may be obtained, by simply planting the carnation in the flower border, and fastening its stem with matting, &c., to a stick.

THE PINK.

The pink is usually regarded as a variety of the preceding. It is, however, much more hardy. It is usually propagated by pipings, *i.e.*, little cuttings separated at a joint, and placed under a hand glass. The after culture of the pink is quite easy.

Other flowers are often considered florist's flowers, as the iris, lily, members of the primrose family, mignionette, and many others. Some of these are excluded in the preceding list of border flowers, and it is not likely that an amateur would bestow upon any of them that constant attention that a florist's flower demands. We therefore omit all special mention of them.

VENTILATION OF APARTMENTS IN DWELLING-HOUSES.

CHAPTER IV.

VENTILATION BY THE CEILING—DR. REID'S CASES AND ILLUSTRATIONS.

The methods of admitting fresh air to an apartment are easily enough carried out; none being so simple, and at the same time efficient, as that which gives a supply to a chamber made behind the fireplace, passing from this into the apartment at the sides or jambs. The great point, however, in connection with new arrangements in house construction, is the getting rid of the foul air, and the natural course which this takes leads attention inevitably to the ceiling. It is in connection with this part of our apartments that a new construction is desiderated before ventilation can be made certain in its effects. "If sanitary reform," says the authority to whom we have already alluded, "be anything but a canting cry—if unnecessary death and disease be things for which any are to account—if the suppliers of dwellings are answerable for economizing at the cost of life—if they have any duty, in building for others (as Israel in building for themselves), to "make a battlement for thy roof, that thou bring not blood upon thy house, if any man fall from thence;" in short, if any man be responsible for human life wasted by human agency—if "at the hand of every man's brother" shall be required "the life of man;" then is this part of every building to be contrived according to whatever our latest science may prove necessary to the free passage of light fluid through it from below, and its retention above when once through." This authority details very fully the method by which he proposes to construct the ceiling, to meet the desideratum above pointed out. The grand essential feature in the construction is, that no portion shall be flat; the ventiducts through which the foul air passes away, and the slopes leading to those apertures, taking up the whole space of roof; these sloping surfaces having the greatest amount of steepness at the point furthest from the ventiduct; the amount of slope recommended being not less than 1 to 1 from its lowest point to the outlet. The number of ventiducts he proposes, is one to each square foot of area; the base of the longest slope not exceeding 9 inches. By this arrangement, the extreme difference of level is included in the depth of the ordinary joists of floors or ceilings. They may be constructed of lath and plaster, but porcelain would answer in every respect much better. "They may be of any quality, from brick to porcelain; remembering that a glaze to diminish friction, though not imperative, is to have precedence of all ornament, *i. e.*, not lawfully to be omitted where there is any ornament. To fit between the joists, they must be of a square-based dome shape, in section like a pointed arch, and their vent, if single, may rise as near to the flooring above as half the width of its aperture; indeed, *should* do so, that the overflowing current may be immediately spread laterally, and not return. Hence, where there is no floor above, it would be better (and where there is one, it would save a little height) to have four vents sloping outwards, from close to the internal apex; and they should be nostril-shaped, every care being requisite to conduct the light fluid, without the smallest obstruction or lodgment, from its first touching the ceiling anywhere, till its safe passage through it. Any lodging-place for it will retain, cool, and send down, like our present ceilings, a constant supply of the poison.

VENTILATION

PLATE I

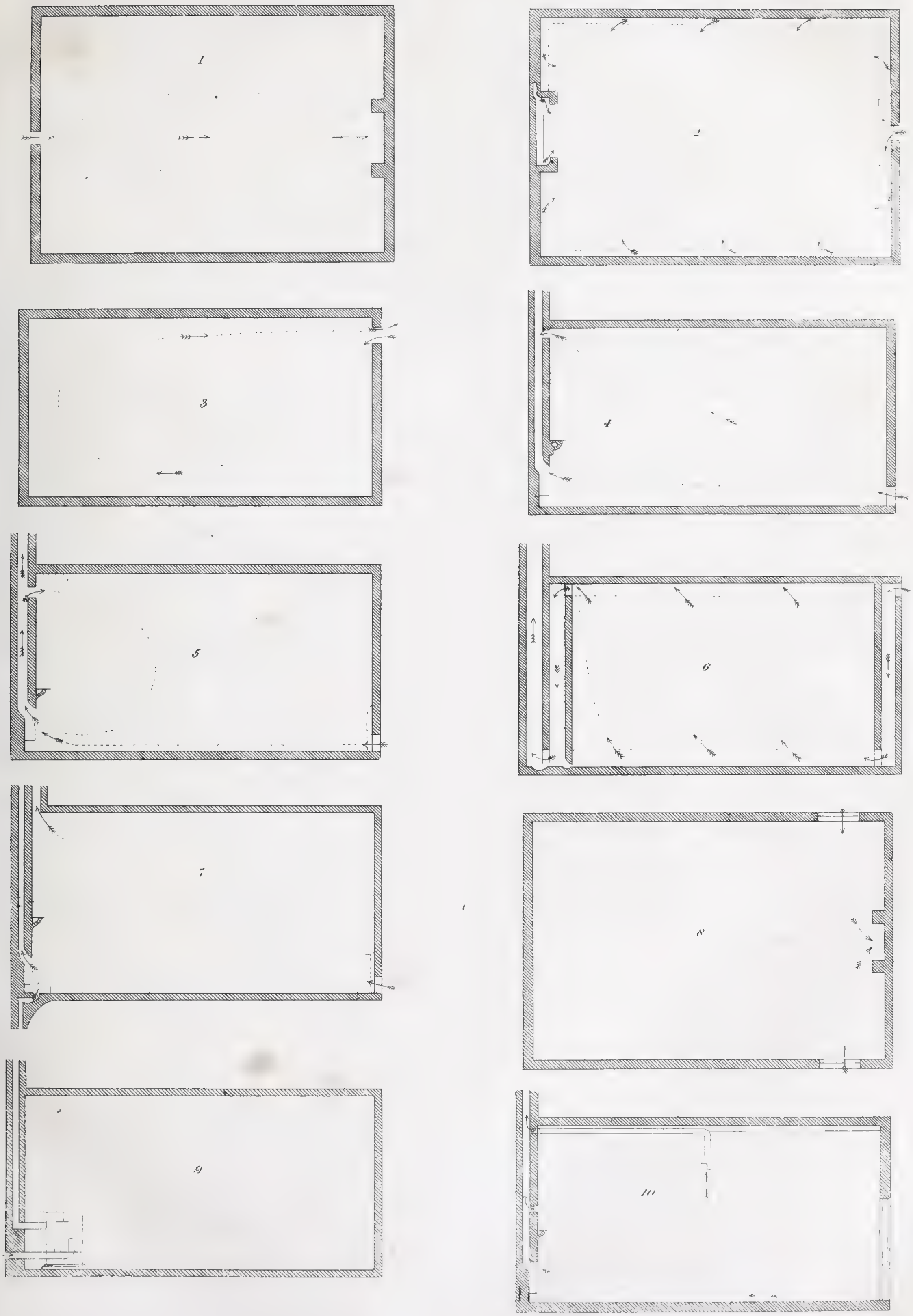


PLATE II

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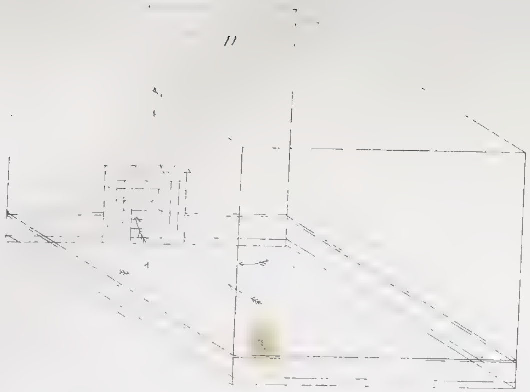

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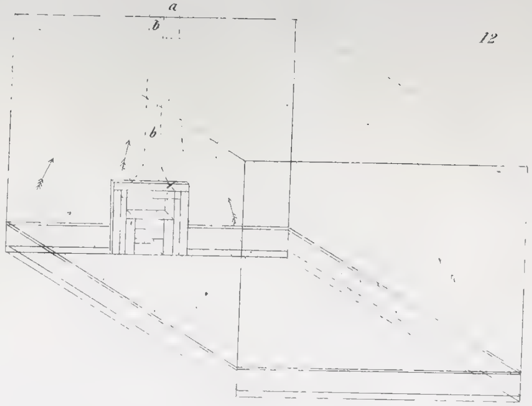

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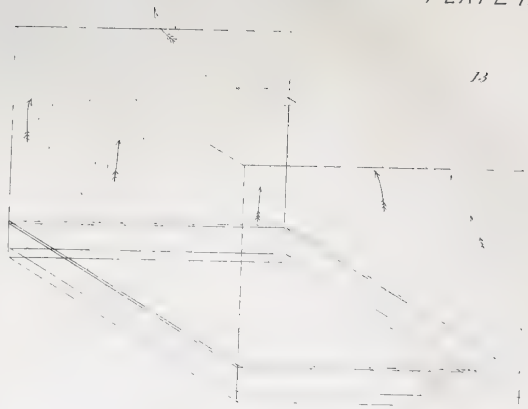


Fig 1

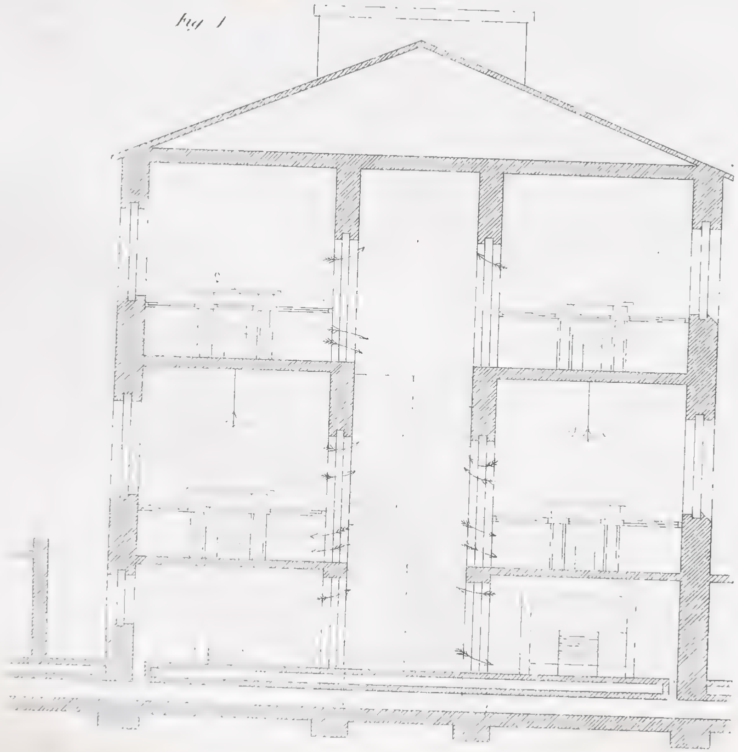
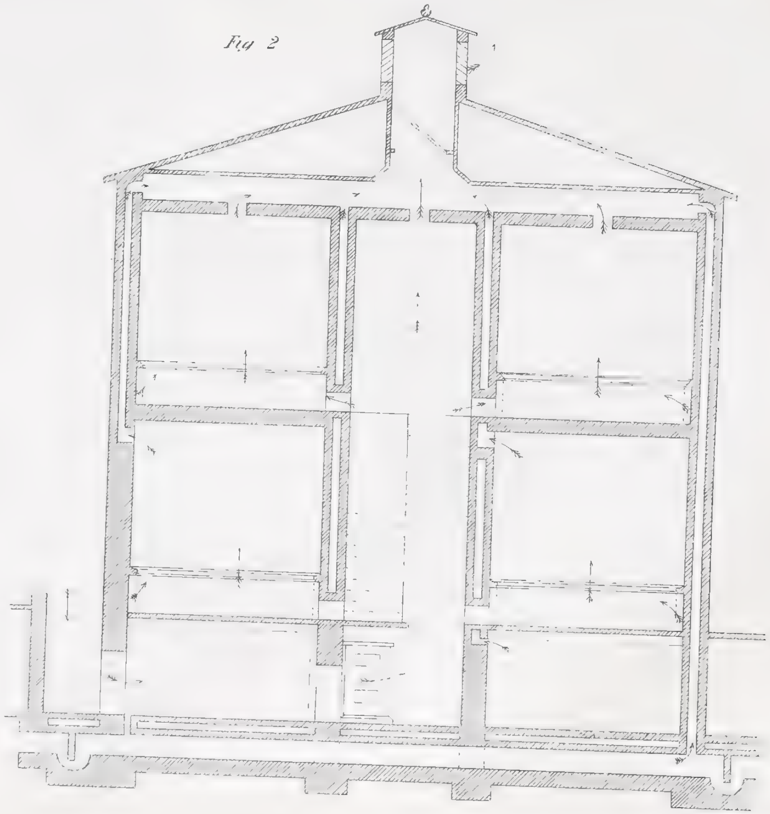


Fig 2



VENTILATION

Fig 1

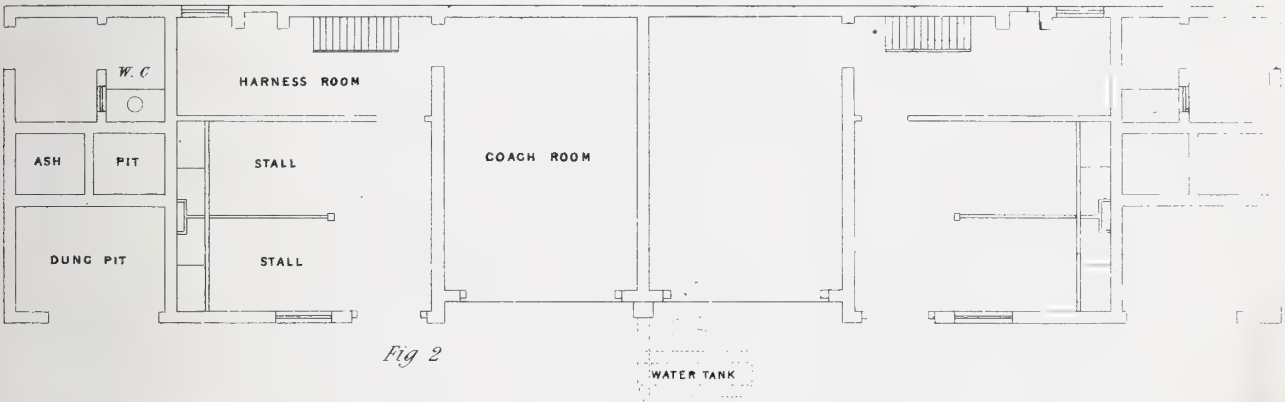


Fig 2

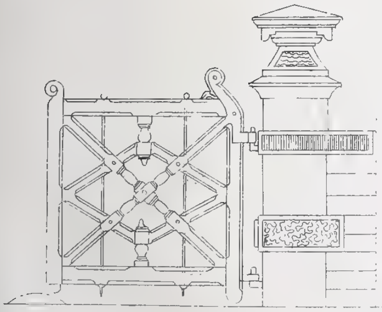


Fig 3

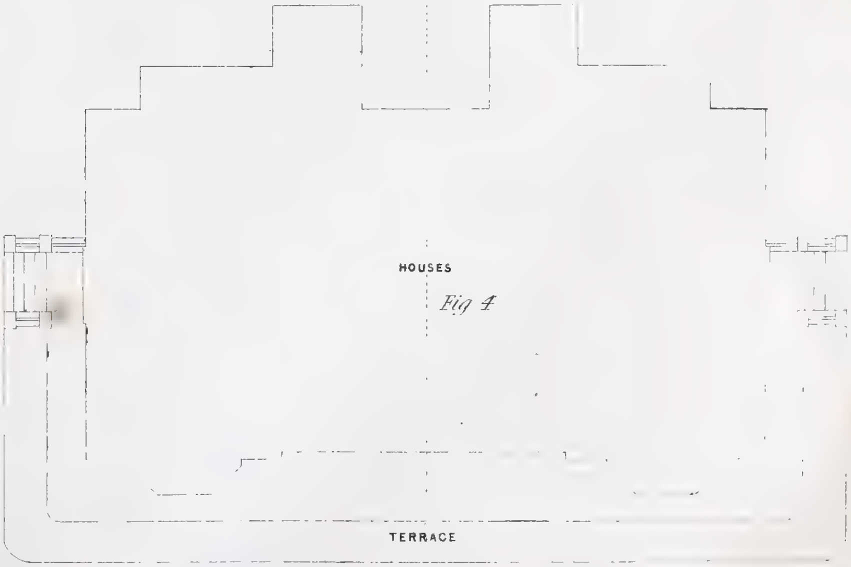


Fig 4

Scale for Fig 1 2.

In. 12 0 1 2 3 4 5 10 15 20 Ft

Scale for Fig 3 1/1 Inch to the foot. Scale for Fig 4 20 feet to the Inch.

Hence the joists dividing one row of these pots from another, must have their under face bevilled off each way, like the cut-waters of a bridge, and similar cut-currents must be formed by the bars (of whatever material), laid across from joist to joist, to receive the edges of the pots, and which will also perform the function of our present strutting. A little mortar thrown into the trenches above these junctions, will make them tight against the downward return of foul air." The foul air thus withdrawn from the room, and delivered to the space between the ceiling of one room and the floor of another, is to be passed to the external atmosphere, through openings made in the wall between every two joists; these openings to be in both walls, so that if the wind blows against one, the opening in the other wall will push the foul air out. As there will be many times in which this action of the wind prevails, thus rendering inoperative one set of apertures, it is necessary that the collective area of the exit apertures in the walls be twice that of the apertures of the ceiling vents. In place of having the exit apertures in the external walls, Mr. Garbett, the author of the plan now under consideration, proposes to withdraw the foul air from the space between the ceilings, by means of the chimney flue of the fireplace, communication being made from every part of the space above the ceiling vents to the opening thus made in the chimney, and valves supplied to prevent sparks from entering the space, in cases where the floor is combustible. Where the floor is fireproof, (see articles in this work on the "Building Arts,") these valves will not be desiderated. It may be worthy of consideration, whether it would not be desirable to have flues made of earthenware tubes, built in the walls, their lower apertures communicating with the space into which the foul air is delivered, and their upper ends opening to the external atmosphere beneath the eaves; or all the tubes might lead into a space surrounding a central flue, through which the smoke from all the chimneys may be led. We are inclined to think that this plan of having flues in the wall, would be efficient in removing quickly the foul air delivered from the ceiling vents. Mere apertures in the walls between the joists would not be so applicable in winter as in summer, and the plan of using the chimney flue is attended with certain disadvantages.

Having thus placed before the reader a resumé, or outline, of the various methods which are in use, or proposed to be used, for the ventilation of apartments in dwelling-houses or workshops, we purpose concluding our article by giving a few admirable "cases," or "examples" of ventilation, showing the movements of air in apartments, and applicable to ventilation of places already constructed, as well as those in erection. In the "Second Report on the Health of Towns," issued by command of her Majesty, Dr. Reid gives a series of "cases" and "illustrations," conveying so much of practical information in connection with the ventilation of dwelling-houses, that we think a selection of the most useful of these will be acceptable to the reader.

Case First, (illustrated by fig. 1, Plate I.)—No ingress can be permitted at the sides, and no egress above; the common fireplace is all that is available for the discharge of air, and it cannot be pierced above the chimneypiece. An aperture may be made opposite the fireplace, but it cannot be higher than two feet above the floor.

Answer (fig. 1, Plate I., plan): The ventilation will never be satisfactory if the room is crowded. The progress of air will be directly from the ingress to the egress by the fire, at a low level; endless revolving currents, at a higher level than the chimneypiece, may or may not produce a sufficient mixture with the leading current below, so as to sustain a proper atmosphere.

Case Second.—The ingress of air can only be permitted at the same place as in fig. 1, case first; there is, however, no objection to subsequent diffusion, and it is an object to sustain a general movement of air throughout the apartment, and to reduce to a minimum the strong currents in the immediate vicinity of the fireplace, such as must ensue in case first, fig. 1. Superior apertures (that is, apertures above the zone of respiration) cannot be agreed to, either for the ingress or egress of air.

Answer (fig. 2, Plate I., plan): The ventilation will be imperfect to a certain extent, as in the preceding case, from the want of a superior aperture. The ingress of fresh air by a flue immediately adjoining the fireplace, will reduce, in proportion to the amount admitted there, the severity of the current impinging on any one near the fire. By opposing a board to the ingress, the entering air may be diffused to any extent around a porous skirting, according to the amount of escape that may be permitted it at different places.

Case Third.—A single aperture can alone be permitted, both for ingress and egress of air; it is required to ventilate as much as circumstances permit, no chimney being in operation, and doors and windows being too air-tight to admit of any discharge.

Answer (fig. 3, Plate I., section): Let the aperture be made at the highest part, of a magnitude proportioned to the amount of discharge demanded. A current will enter, in general, by the lower portion of this aperture, while a corresponding current passes outwards by the upper portion. This movement will always be induced, when the air in the interior of such an apartment is warmer and lighter than the external atmosphere. No ventilation, however, can be expected where the air is colder and heavier than that without; the air will then remain stagnant, in the same manner as water in a well. In this case, where an aperture can be made below only, then an interchange might be expected, as the warmer and lighter air would enter and ascend, displacing the colder air through the lower part of this lower aperture.

Case Fourth.—Diffusion can be obtained extensively at the skirting. Objections are entertained against any superior aperture in the outer wall; the chimney has a powerful draught; it is required to carry off air by a superior aperture, as well as by that which the common fireplace presents.

Answer (fig. 4, Plate I., section): Pierce the chimney in the upper part of the wall, near the ceiling; let the aperture be defended from fire or heated air, and capable of being shut absolutely air-tight by a metal valve, which can be so securely fixed in its place as to prevent all return of heated air. In any extreme occasions, when this may be apt to take place, or such recoil as may ensue when the fire declines, and becomes nearly extinguished, and the power of the chimney becomes proportionally reduced—let a copious ingress of air be always maintained, so as to satisfy the demand of the fireplace, and of the discharge by the aperture near the ceiling. Though the chimney has a powerful draught, the ventilating aperture will work well or indifferently, according to the supply of air and the temperature within and without.

Case Fifth.—If the supply of air be too small, though it may be traced entering at the proper aperture—if the fire be too strong, and the opening immediately above the grate be uncontrolled by a valve—and still more, if the aperture near the ceiling be too large, then a dangerous recoil is apt to ensue, as indicated in fig. 5, Plate I., section. This, in reality, is only a variety of one of the most common movements of air, when back smoke vitiates the atmosphere of any apartment.

Case Sixth.—It is required to sustain at all times a steady and uniform ascending current through an apartment, where it is important not to admit air at the level of the ground, and where it is impossible to apply mechanical power, or to carry an elevated chimney to any considerable height above the level of the ceiling.

Answer (fig. 6, section, Plate I.): Let air be taken in by an aperture at the highest accessible altitude; let two tubes be formed within the apartment, the first to convey air from the ingress aperture, A, to the floor, where it may be diffused to any desired extent (by openings, or a perforated flooring); and the second to convey it from the ceiling, entering at C, to the fireplace, F, where a gas-light, a fire, an oil lamp, a steam pipe, a hot-water coil, a stove, or any other source of heat may be applied to sustain, without interruption, the desired movement.

Case Seventh.—It is required, in an ordinary apartment, where the chimney flue cannot be touched, in consequence of a tendency to smoke, to combine the advantages of a superior discharge with those of an open fireplace, reducing the current in the vicinity of the fireplace to as great an extent as may be practicable.

Answer (fig. 7, Plate I., section): Let a free ingress for general ventilation be permitted, with all the diffusion that circumstances will permit; let a separate supply be given in the immediate vicinity of the fireplace, as ample as the fire can consume, allowing for the great expansion which the air undergoes in its progress to the chimney; let the open space between the chimneypiece and the grate be reduced as much as is compatible with a free use of the fire; let the valve in the chimney flue (immediately above the chimneypiece) close this flue as much as is consistent with the removal of the products of combustion, and the rapidity with which it may be required that the fire shall burn; by a spare flue, or some other superior aperture, let the vitiated air be carried off and discharged, but not in the immediate vicinity of the chimney top, where the fire flue terminates.

Case Eighth.—It is required to ventilate powerfully one end of an apartment near the fireplace, but to sustain the atmosphere in the rest of the apartment, with no more ventilation than that which is sustained by the more gentle and secondary movements that are consequent in direct ventilation.

Answer (fig. 8, plan, Plate I.): Let the ingress be so arranged, that the direct progress of the air between it and the discharging fireplace, shall involve the space where the greatest ventilation is desirable. The movement is less in every other portion of the apartment, according to its distance from the leading current, and may be proportionally charged with bad air.

Case Ninth.—The ventilation effected by crevices in doors and windows, is as much as can be permitted; everything would be satisfactory, were it not for the return of the vitiated air from the stove.

Answer (fig. 9, section, Plate I.): Permit a larger ingress of air, so that the stove may have a sufficient supply, or adjust valves so as to prevent return; and if it should be required to dispense with valves altogether, and to sustain an atmosphere perfectly free from all return let an opening be established to supply the stove with fresh air from without, so that at times, however feeble the current may be, any returning movement shall neither arrest the progress of combustion, nor be the cause of any ingress of vitiated air into the apartment. In stoves constructed in this manner, the products of combustion, except when the flue is kindled or fed, may be considered as hermetically excluded from the apartment. In many buildings in the northern countries, they are kindled and fed from without, where there are appropriate corridors and passages.

Case Tenth.—The ascending products of combustion from gas-light, cause a corresponding descent of vitiated air, with which the head and superior extremities may be surrounded, though the feet are bathed in a cold atmosphere. It is required to carry off those products, so that the air should no more be contaminated by them, than if they were not formed within the apartment.

Answer (fig. 10, section, Plate I.): Let a superior ventilation be established to such an extent, as to involve and carry away all the products of combustion; or let burners be arranged in such a manner, or provided with appropriate tubes, securing them as effectively as a good chimney flue withdraws the products of combustion from a common fire.

Case Eleventh (fig. 1, Plate II., section).—A house is filled with vitiated air, from products of respiration and combustion, drains, and back smoke. The rooms in the upper story afford the principal supply of fresh air by their chimneys, no other source being open. The great consumption of the kitchen enables it to draw largely from the passage, which again receives its supply from the rooms above. While those more general movements proceed in the manner indicated by the arrows, local currents are developed in the other apartments, by lamps and fireplaces, as well as by individuals respiring the vitiated air, and these are also indicated by the arrows. It is required, during the progress of alterations, when the house is nearly rebuilt, though the same general arrangements are retained, to make provision for such movements of air, as can be effected with the aid of a single stove, and a gas-lamp in the channel of discharge.

Answer (fig. 2, Plate I., section): Let an Arnott's stove, or any equivalent apparatus, be placed in the lower part of the staircase, and let air enter so freely, that it is continually flooded with a warm atmosphere, tending, from its warmth, to escape upwards, wherever an aperture is permitted. Establish communications between the passage and each apartment to be ventilated; let them not open abruptly into the apartment, but with such diffusion as may be required; let valves and appropriate channels regulate the discharge from each apartment; let them all unite in a general hot chamber in the roof, and let an additional valve regulate the general discharge. Let the drains be trapped, and a ventilating flue receive such products as might otherwise be discharged into the rooms.

In figs. 3, 4, 5, and 6, Plate II., are given illustrations of the methods of ventilating isolated or detached cottages. Fig. 3 is the ground plan; fig. 4 the chamber plan; fig. 5, a section through A A; fig. 6, a section through B B. By direct experiment, Dr. Reid found that a flue, 9 inches square and 17 feet high, could command four fireplaces, each sufficiently large for any ordinary apartment, were no air permitted to pass into the flue beyond what was requisite for the consumption of fuel. As a general rule, preference is given to a flue, 9 inches by 4½ inches area, for a room of about 12 feet square; smokeless fuel being used, and the flue never requiring, accordingly, to be swept.

The progress of air in unventilated and ventilated apartments, is shown in the illustrations 10, 11, 12, in Plate I. Fig. 11 indicates the progress of air in an ordinary apartment, the air entering at the skirting, and proceeding to the fireplace; the air in the rest of the apartment being very little affected. Fig. 12 shows a different movement, the valve of the fireplace being closed, so as to diminish the amount of air conveyed there, and a superior opening discharging vitiated air at a higher level. Fig. 13 points out the more equable movement of warm air, entering by the skirting, and proceeding to a central discharge, no fire being in action to determine a local current.

The following works on this subject may be consulted with advantage:—"Bernan's History of Warming and Ventilating," an exceedingly interesting and instructive work—contains much valuable information on the history of the art, and a description of the various methods proposed, from the earliest times, 2 vols. "Tredgold on Warming and Ventilating," 1 vol. "Walker's Useful Hints on Ventilation," 1 vol. "Burn's Practical Ventilation," 1 vol. "Weale's Rudimentary Treatise on Warming and Ventilating." "Weale's Student's Guide to Measuring and Valuing Artificer's Work," contains a large amount of useful hints on the construction of buildings (by Mr. Garbett), in connection with ventilation. "Hoskings' Healthy Homes." "Reid's Illustrations of Ventilation." "Arnott's Treatise on Ventilation."

CONCHOLOGY.

CHAPTER II.

CLASS FIRST.—MOLLUSCA.

The animals which inhabit shells of this class are soft, without articulations of any kind. They are provided with a head, which is furnished with tentacula, or having arms which are disposed in the form of a coronet. Almost all the species have eyes, and a mouth, which is either elongated, short, or tubular; usually extensile, and armed with hard processes for the mastication of food. The body is generally partly invested with a process called a mantle, with free edges on the sides of the body. In some instances the body is destitute of any shelly covering, and frequently enveloping an internal, simple, testaceous plate.

ORDER I.—HETEROPODA.

Head distinct with two eyes, but destitute of arms arranged around the head; the body free, elongated, and fitted for swimming horizontally; destitute of a foot under the abdomen

or throat for walking; provided with one or more fins, without any regular order, and not arranged in pairs, as in fishes.

Genus.—BELLEROPHON.—*Montfort.*

Generic Character.—Shell thick, univalve, unilocular, involute, umbilicated on both sides; nearly symmetrical, bicarinated, and almost spherical, the last volution enveloping the others; aperture very large, semilunate, arched, and terminated by the extremities of the columella, or axis, which is transverse, and provided with a sinus or notch in the lip between the keels.

Bellerophon hiulcus. Plate III. fig. 1.

The shells of this genus are known only in a fossil state, and are characteristic of the carboniferous limestone, and of the strata belonging to the oldest secondary formations; in the latter situation, the shells are frequently changed into silex.

Naturalists have been much puzzled with the species of this genus. They have been described by some as chambered shells, and as provided with a siphuncle; but Defrance has satisfactorily disproved this opinion. There can be no doubt that the animals which inhabited shells of this genus were closely allied to those of the Argonautæ. Dr. Fleming has considered *Bellerophon* as nearly connected with *Tornatella*, and placed it accordingly after that genus in his family Tornatelladæ. We are, however, convinced, that its proper situation in the system is where we have now placed it. They differ, however, in two particulars, viz., in the nearly globular form of the shells, and in being very thick; while those of the genus *Argonauta* are very thin.

The genus consists of two sections:—1. With a mesial band. 2. Destitute of a mesial band.

ORDER II.—CEPHALOPODA.

The head of the animal projecting from a sack-shaped body, and provided with a series of inarticulated feet, each of which are furnished with cup-shaped suckers, placed around their heads.

GRAND DIVISION I.—CEPHALOPODA SEPIARIA.

This includes the cuttle-fish, which are destitute of a shelly covering.

The division *Teuthidæ*, which include the cuttle-fish, belong to the decapodous division of the *Dibranchiate Cephalopoda.* The animals are provided with ten arms, two of which differ in length, as well as in shape and in their manner of insertion, from the rest, and are generally termed tentacula. These arms are furnished with stalked suckers. The head has two eyes, which are capable of free motion. The siphon is usually provided with a valve. The form of the body is frequently elongated, and always furnished with fins on the sides. Their shell is internal; in some species it is a horny pen, and in a few it is that substance called cuttler's bone; more rarely it is a chambered shell, variously combined with pen, or bone, or gourd.

Sepia officinalis. Plate I. fig. 34.

This is a recent animal, to give a general form of the tribe.

Genus.—LOLIGO.—*Lamarck.*

Body fleshy, firm, cylindrical, elongated, and, towards its posterior extremity, it is provided with triangular fins on each side, which extend to the tail; its organs of progression consist of two oblong margined pits, situate at the base of the funnel, and with corresponding linear prominent crests on the inner margins of the sleeve. The eyes are covered by an epidermic expansion, pierced with a small opening, and are destitute of a lachrymal sinus. It has ten arms, two of which are tentacular, imperfectly webbed. Pen corneous, flexible, and lanceolate, as long as the body, terminating in an obtuse point.

Fragments of fossils of this genus have been found at Lyme Regis, Dorsetshire, and several of these have been figured by Dr. Buckland in his " Geology, &c., considered with reference to Natural Theology." (See Plates XXIX. and XXX. of Vol. II.) The most perfect portions of these remains are the ink bags. These are frequently found with the ink completely petrified. Plate I. fig. 28, is an ink bag from Lyme Regis, quite distended with ink.

GRAND DIVISION II.—CEPHALOPODA MONOTHALAMA.

Shell unilocular, entirely external, and enveloping the animal. No fossils of this division have yet been discovered.

GRAND DIVISION III.—CEPHALOPODA POLYTHALAMA.

Shell multilocular, either entirely or partly internal, and situated on the posterior portion of the body of the animal.

The fossil shells of this division are very numerous, and widely diffused through different strata.

TRIBE I.—AMMONACEA.

Septa sinuous, lobed and cut at the margin, and meeting together upon the inside of the shell, where they are articulated by serrated sutures, furnished with a siphuncle, which penetrates through the whole of the partitions or septa.

In all the genera of this family, the chief variation consists in the external form of the shells; the internal structure of the whole being similar, and intended as a float, subservient to the animal inhabitants.

Genus.—HAMITES.—*Parkinson.*

Generic Character.—Shell usiform, cylindrical, hooked or bent into two parallel limbs, recurved at the posterior extremity; exteriorly undulated; chambered, with the septa undulated at their margins, and the siphuncle placed at their outer edge. In some species, the siphuncle has a keel-shaped pipe raised over it; others have a series of spines on each side of the ambit, or back of the shell.

Hamites annulatus. Plate III. fig. 2. Found in the ferruginous Oolite.

Hamites are found in the baculite limestone of Normandy; and a few small species are met with in the chalk marl of Folkstone.

The most simple form of the shells of this genus may be conceived by supposing a baculite to be curved round near its centre, until its smaller extremity becomes nearly parallel to its larger end. Some of the species are more tortuous, and are either coiled up in the form of a *Spirula*, or considerably less spiral. These two forms bear the same relation to *Ammonites* that the shells of *Lituola* bear to *Nautilus*, each having a form as nearly as possible what these genera would respectively exhibit if partially unrolled.

The Hamites and Baculites possess two characters which connect them with the Ammonites. First, the siphuncle is situate on the ambit or outer margin of the shell. Secondly, the transverse plates have a foliated structure at their margins, where they join the external envelope or shell. In the Hamites, the external shell is also strengthened by transverse ribs or folds, which serve not only to increase the outer chambers, but also the air chambers, upon the same principles as in Ammonites, as we have shown at page 14.

There is a strong probability that the shells of this genus were partly internal and partly external; those with spinous appendages were, most likely, external envelopes.

The Gault or Specton Clay, near Scarborough, Yorkshire, which occurs immediately under the Chalk, contains not fewer than nine species of this rare genus. Some of these (the *Hamites grandis* in particular) are as thick as a man's wrist.

No recent species of Hamites have yet been discovered.

Genus.—BACULITES.—*Lamarck.*

Generic Character.—Shell straight, conical, symmetrical, cylindrical, a little compressed laterally in some instances; partitions articulated by sinuous sutures; septa close, transverse, and imperforate with marginal lobes and lacinations; being divided into dorsal, central, and lateral lobes, the external chambers larger than the rest, swelling, and capable of containing a considerable portion of the animal; aperture elliptical, and provided with a dorsal siphon.

Baculites Faujasii. Plate II. fig. 3. Found in the mountains of St. Peter, neighbourhood of Maestricht. No recent species of this genus have hitherto been discovered.

This genus may be distinguished from the Orthocera, by its septa being much lobed and sinuous.

The genus Baculites takes its name from a resemblance to a straight staff. It may be considered as a straight Ammonite; for, as in that genus, the transverse plates are sinuous, and terminate in foliated dentations at their union with the external shell. The species of this genus are found in the Cretaceous formation alone.

Buckland remarks, it is a singular circumstance that this straight modification of the form of *Ammonites* should not have appeared until this family had reached the last stage of the secondary deposits, throughout which it has occupied so large an extent; and that, after a comparatively short duration, the Baculite should have become extinct simultaneously with the last of the Ammonites, at the termination of the Chalk formation.

The outer shell of the Baculites is thin, but, like that of the Ammonites, is strengthened by oblique ribs; near the posterior margin of the shell, the transverse plates are penetrated by a siphuncle. This character, and the sinuous form, and denticulated edges, and transverse plates, are characters common to both this genus and Ammonites.

Genus.—Turrilites.—*Lamarck.*

Generic Character.—Shell spiral, multilocular, turreted, with contiguous volutions coiled around themselves in the form of a winding tower, and gradually diminishing towards the apex, the whole being perceptible; walls articulated by sinuous sutures; with close transverse septa, lobed and laciniate at the margin; siphuncle situate near the dorsal margin; outer chamber large; aperture rounded, with an expanded outer lip.

Turrilites Tuberculatus. Plate III. fig. 4. Found in the Marl stratum at Middlesham, parish of Ringmer, Sussex.

The shells of the genus Turrilites are extremely thin, and their exterior is ornamented and strengthened with tubercles and ribs. They resemble in every respect the Ammonites, except that they are straight, with a produced spire, instead of being coiled. Their internal cavity is divided into many chambers by transverse plates with foliated edges.

The species of this genus are known only in a fossil state.

Genus.—Crioceratites.

Generic Character.—Shell multilocular, convolute, with the volutions disunited, or not rolled upon one another.

Crioceratites Duvallii. Plate VI. fig. 1.

Genus.—Goniatites.—*Von Buch.*

Generic Character.—Shell discoidal, generally convex or nearly globose; most of the species deeply umbilicate; the inner volutions much or wholly concealed, being generally enveloped in the outer one; provided with internal partitions, or septa, and lateral and dorsal lobes and sinuses; siphuncle situate near the ambit; it is not, however, a continuous tube, but passes naturally from the septal plate a short distance.

Goniatites Henslowi, Plate I. fig. 6. *G. sphericus*, Plate III. fig. 7.

This genus was formerly included among the Ammonites, but was separated by Von Buch. It is unknown in the superior strata. The septa, lobes, and sinuses differ from those of *Nautilus* and *Ammonites.* (See Plate I. fig. 2.) The parts are included within lines—D, the dorsal region; L, the lateral region; and M, the marginal or umbilical region; *a b c* marks the lobes, and *e e e* the sinuses; the siphuncle is distinguished by S, and is situated in the centre of the dorsal lobe, immediately beneath the barb of the arrow which marks its centre. This belongs to *G. striatus.*

The *Goniatites Henslowi*, Plate I. fig. 6, is one of the earliest forms of this genus, and which becomes extinct with the Transition series. It is found in the Transition Limestone in the Isle of Man.

Goniatites sphœricus, Plate I. fig. 13, is a longitudinal view, introduced to exhibit the character of the lobes. It shows the position of the siphuncle, situate upon the dorsal margin, with its collar protruding outwards, and situate between the two simple dorsal lobes; the lateral lobes are also simple, destitute of foliations, and are pointed inwards.

Genus.—Schaphites.—*Parkinson.*

Generic Character.—Shell chambered, involute; its first volutions small, and increasing very gradually; its last elongated and dilated or expanded; the division of the chambers lobed and sinuous. It appears to be almost, if not wholly, internal.

Scaphites equalis. Plate III. fig. 9.

This genus is allied to *Ammonites*, but differs considerably in its general form, in consequence of the singular extension and inflation of its last chamber. The species are found, very rarely, in the three contiguous strata, the Chalk, Chalkmarl, and Greensand of Wiltshire and Sussex in England, and similar beds near Rouen in Normandy.

Genus.—Ammonoceras.—*Lamarck.*

Generic Character.—Shell horn-shaped, arcuated, subsemicircular; the walls articulated with sinuous, laciniate, branched sutures; provided with transverse, sinuous, and imperforate septa; having lobed, laciniate margins, furnished with a marginal siphuncle, which does not perforate the septa.

Ammonoceras glossoidea. Plate III. fig. 6. Found only in a fossil state, in the East Indies. It is of large dimensions, measuring upwards of nineteen inches in length.

Sowerby is of opinion that this genus should be united to that of *Ammonites*, and thinks the specimen from which Lamarck took his generic character was only a worn shell of that genus.

Genus.—Orbulites.—*Lamarck.*

Generic Character.—Shell subdiscoidal, spiral, with contiguous volutions, the last enveloping the inner ones; the interior wall articulated by a sinuous suture, septa transverse, lobed at their circumference, and perforated by a marginal siphuncle.

Orbulites striatus. Plate III. fig. 10. Locality unknown. Known only in a fossil state.

Sowerby thinks that this shell should not rank as a distinct genus, inasmuch as he considers the circumstance of the last volution covering the others as an insufficient distinctive character. In this, however, we differ from him.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER I.

ORIGIN OF SCIENTIFIC RESEARCH—PROVISIONAL PHILOSOPHY.

To treat of origins is always difficult. No written or traditional records exist which might inform us when and how man first began to speculate—to explain to himself the world in which he stood. Much, however, we may with safety infer from the nature of the human mind, from the observation of children, and of tribes who have remained in a primitive condition. That such commencement was early, there can be no doubt. To suspend judgment is natural to none, and is artificially attained but by few. The ignorant are rarely at a loss how to designate, or, in their way, to account for, the most unusual object or occurrence. The earliest inhabitants of our planet would not long hesitate before doing the like. Gazing upon heaven and earth, they uttered the great word, WHY? and an answer which appeared satisfactory enough was not wanting. What was their conception of the universe, no book, no inscription tells us, and fortunately none is requisite. The life of the race is shadowed forth in that of the individual. Observe a young child, and ask yourselves—how then does he conceive of and interpret all things around him? Do we not find him talking to, caressing, or at times perhaps beating his toys, or any inanimate object with which he is familiar? Does he not, in a word, attribute to them all his own sensations, thoughts, emotions, deeming them living as himself? Look

again at savage nations. To them the whole world is animated; all nature is peopled by demons and genii, who produce the various phenomena that strike their attention. The sun, moon, and stars were deities; eclipses were caused by some fearful monster to devour the sun; thunder was the voice of an incensed god; the northern lights were a dance of spirits. Nor was this personifying tendency confined to those whom we denominate savages; with certain refinements it entered largely into the mythology of Greece and Rome. What were the Oreads, the Dryads—nay, what were Vulcan, Apollo (as sun-god), but powers of the universe viewed in human form? What was Pan, but that great universal entity Nature, with which so many of us still love to be mystified. We may go yet farther. To the miner in the middle ages, in the last century even, explosive gases seemed the action of a hostile demon, slaying with his fiery breath the adventurous mortals who dared to ransack his treasure-house. The sylphs, undines, gnomes, or cobolds, and salamanders of Paracelsus and his contemporaries, are all proofs of the same tendency. Nay, even in us it is not quite extinct. The careful observer will sometimes detect himself, half-consciously, lending to lifeless objects passions and feelings like his own.*

Such then was the dawn of philosophy: the earliest men beheld in the world a collection of beings endowed with life like themselves. "Man, the measure of all things," was the fundamental principle of their doctrine—a principle which to this day holds many in bondage. Their method of proceeding was from within outwards, from the human mind to the external world. That this principle is false—this method, to say the least, partial and one-sided—commencing as it does with the complex, and proceeding afterwards to the simple and rudimentary, is undeniable. And that we have rejected the principle and reversed the method is, doubtless, good cause for rejoicing. Yet we must ever bear in mind that this primitive philosophy—if we may so style the mystic web of symbols blending science, poetry, and religion into one—this philosophy of our earliest forefathers was valuable, necessary. It was a stage through which the development of the world must needs pass—the seed-leaf, as it were, which the human intellect first put forth in its yearnings for the rays of truth. That the use of such a seed-leaf is transient, that it is destined to wither as the true leaves appear, detracts nothing from its importance. We shall find it, upon examination, the only philosophy then possible. Facts had not been collected upon which a more correct theory, a positive, inductive philosophy like ours, might be built. And again, without some theory, the observation of facts is for the most part vague and fruitless. We must have a definite question to propose to dame "Nature," before we can hope to receive a definite answer. And a more cross-grained old lady, be it remembered, never was put in the witness-box in any court in Europe. The personifying or supernatural doctrine here stepped in to the rescue—extricated man from his dilemma, and aided in the collecting of those very facts and observations by which it was ultimately rectified, or rather superseded. The imagination, in the race as in the individual, is more early developed than the reason; hence the strict propriety, the suitableness of an imaginative philosophy for the primitive world. It was milk for babes, to whom strong meat would have been indigestible, perhaps poisonous. Nor was this view less adapted to the habits and propensities, than to the intellectual state of the primal world. Man, we know, is naturally averse to systematic, prolonged industry of any kind. The savage, like his four-footed neighbours of the forest, when not under the stimulus of some pressing want, coils himself up in listlessness or sleep. With what spirit, then, would the early inhabitants of our planet have entered upon the slow and toilsome process by which physical truth is ascertained, and applied to elevating the condition of man? Would they not have renounced, as hopeless, all attempts at progress, of exercising dominion over the external world, had they been aware of the unchanging nature of its forces? But here was a system which promised much at the expense of small labour. Those elemental genii, demons and gods, which—whether regarded as one with matter, or as distinct tutelary powers—were supposed to regulate its course at their will, might, it was suggested, be influenced to become the allies of man, and to exercise their power for his benefit. Here, then, was hope for man in the conflict with nature. Nor were the speculative triumphs promised by the primitive philosophy less alluring than the practical. It solved, to appearance, all questions, not on the slow and painful track of experiment and induction, but with a bound. It offered to lead man to the very fountain-head of all truth—to teach him, not merely the laws, properties, and mutual relations of things, but their inmost nature, their first and final cause. Such inquiries, we now know, are beyond the reach of human reason; and if science now makes rapid progress, it is because we have consented to lay aside all these investigations. But the very magnificence of the offer insured its acceptance. In the early world, as, alas! among the uneducated in our own day, he who promises most finds the readiest belief.

Let us now take a somewhat closer view of the personifying philosophy, which we have found so admirably adapted both to the speculative and the practical requirements of the early world. It was, in the first place, intimately connected with the religious views of the times, or rather, it was at once a philosophy and a religion. The principles which animated nature were regarded as deities, and the rites taken to insure their protection or avert their wrath were worship, sorcery. Spells, charms, invocations, sacrifices, instead of experiment and observation, were the methods by which science was to be advanced or the arts improved, when success was expected only from a supernatural revelation. A philosophy created by the imagination could not be separated from poetry. Transferring human passion into all nature, pouring out its mystical precepts in vague and allegorical language, it approached as near to poetry as to theology.

But further, the various sciences were not separated. The time of analysis was not yet come. There was no chemistry, astronomy, physiology; there was the one all-including doctrine, *wisdom*, so called, in the earliest signification of the term. Inwardly, as outwardly, there was no division of labour. Without examining phenomena in detail, the primitive philosophy drew a bold and animated, though faulty picture of the universe, suited to the tastes of an imaginative epoch. Here it differed most strikingly from the science of the present day. If our forefathers rushed into premature generalizations, if they neglected to verify their theories by an appeal to facts, we fall into an opposite error. Losing ourselves in petty details, we avoid too often all system, all theory, forgetful that facts only become of real value when rightly combined into one harmonious and truthful whole. A leaf may be very beautiful, but it can be rightly appreciated only when viewed in connection with the plant of which it forms a part. The collection of isolated facts is a needful preliminary, but nothing higher. The work of the architect is not at an end with the mere accumulation of building materials.†

Here also, as extremes meet, the science of the past resembles that of the future. In both, synthesis is the grand feature. But in the past it was undertaken prematurely, without foundation save in dream-world; in the future, it will rest upon the immovable base of analytical research.

* The personifying tendency is not equally strong in all nations, as is betrayed in their very language. Some, *e. g.*, apply the words answering to 'he' and 'she' to lifeless objects; the English, on the other hand, rigidly restrain these pronouns to animals, if not to the human species alone. The Irish are much more prone to personify than the English. The same distinction appears in literature. Compare Dante with Milton or Shelley. The former paints his images of dread with all the distinctness of outline presented by a human form; the idea is ready to be seized by the sculptor. The English poets, on the other hand, seek to depict a principle rather than a person. Of Milton's Death we read—

"If shape it could be called, which shape had none;"

and, in like manner, Shelley's Demogorgon is described as

"Ungazed upon and shapeless, yet we feel
It is a living spirit."

It is needless to add, that the personifying nations are the better calculated to excel in the fine arts.

† This neglect of system, we may remark, is one cause of the unpopularity of science. The public are wearied with the minute phenomena, and the technicalities which we offer to their view. They demand results, not methods; general conclusions, not scattered facts; the finished temple of truth, not the scaffolding, stone-chips, and mortar—heaps that tell of its erection. It is by complying with this demand alone that we can win for science real social efficacy, and make good its claims upon the attention of the world.

Again, the provisional philosophy of old, not content with exploring the laws of the universe, ascended to its origin, and took the form of a cosmogony. Every philosopher felt himself bound to explain—"how heaven and earth rose out of chaos." To pass over origins as utterly inaccessible, is a piece of modesty which man was slow in learning. Some of these dreams, blended with the theological views of the people among whom they originated, have been handed down to us, and give ample evidence of the wisdom of abstaining from all such speculation. To the *why* and the *whence* then asked, instead of the less presumptuous *how* of modern philosophy, an answer was indeed rarely wanting; but that very answer involved new doubts, new difficulties. Behind each mystery solved, others appeared, like the heirs of Banquo, in a line stretching "to the crack of doom."

This provisional philosophy was, of course, not confined to any one country; in a more or less developed form it was common to all nations, but attained probably its highest perfection in India, Egypt, and Assyria. What discoveries were made under its auspices, and by what thinkers it was cultivated, are points that must probably remain for ever unknown. The priesthood seem to have been its chief organs, as we might indeed surmise from that theological character which it uniformly wears.

That its effects were, at first, highly beneficial, we have already stated. Every good, however, becomes an evil, if it stands between us and something better. Though the provisional philosophy, up to a certain point, had fostered the up-spring of human intelligence, by giving a direction and definite purpose to its struggles,—though it had encouraged man in his great contest with the material world, it ultimately acted as a drawback. From the very earliest period, we must bear in mind, the germs of a more perfect philosophy had been in existence, and in the course of time they began to germinate. Man, in that intercourse with the external world which his bodily wants required, found indications of something alien and hostile to the prevailing doctrines. Observations, even undertaken at the bidding of the supernatural philosophy, furnished weapons for its overthrow. The eye, turned towards the stars in superstitious devotion, began to perceive phenomena utterly at variance with the supposed arbitrary and capricious sway of gods and genii. In the simpler orders of facts, mankind began to recognize that unvarying regularity which alone renders science—in the strictest sense of the term—possible, and which excludes altogether the notion of arbitrary will. In fact, as Adam Smith happily observes, man never invented a deity to account for the phenomena of weight.

A contest now commenced. The primitive doctrine, seeking to maintain its ground against the new truths, became stationary, and even retrograde. When it succeeded, society, as in most regions of the East, became immovable, and presents to this day merely the fossil remains of bygone spiritual activity. Elsewhere the new ideas gained the ascendancy, and a complete change in man's conception of the universe, in his habits of thought and in the structure of society, was gradually effected. Although individual thinkers in the East, such as the Hindoo Kanadi, may have reached this phase of mental development, it was in Greece, and the Ionian shores of Asia Minor, that the revolution became general, permanent, and efficacious. We must not, however, mistake the nature of the change in question, by supposing it too sudden. Mankind could not overleap the vast chasm lying between the doctrines of the primitive ages, and the philosophy of the modern world, as constituted by Bacon and Descartes. To pass at once from the worship of a thunder-god, to an experimental and mathematical investigation of the laws of electricity, was impossible. A transition stage was needed, and such, accordingly, we recognize in the intellectual activity of Greece. This transition stage has received the perhaps inappropriate name of "metaphysical," which, however, for want of a better, we shall continue to employ. From the former, or primitive stage, it differs in no longer regarding all objects as animated, or as superintended by tutelary genii, and subject to their arbitrary control. From the modern positive philosophy, it is distinguished by still pretending to a knowledge of the inward nature or "essence" of things, and by inquiring into the primary causes of phenomena. These it endeavours to explain by "entities," tendencies, principles, and other incomprehensibilities, which are, in fact, only the demons and gods of the former epoch slightly disguised. If the supernatural philosophy had referred light to the will of Apollo, of Balder, of Hé-coch, the metaphysical explains it in the following terms—"Light is the act of transparent, in so far forth as transparent." The former had ascribed the soporific action of opium to the demon of the poppy invading and overpowering the human brain; the latter informs us that opium brings on sleep, because it has a "sleepy tendency." The primitive world perceiving water rise in a common sucking-pump to the height of thirty feet and no further, solved the difficulty by the caprice of a water spirit. In the metaphysical period, it was declared that "nature" abhors a vacuum for the first thirty feet, but no further. We explain the fact, by showing that a column of water thirty feet in height exactly counterpoises the pressure of the atmosphere. The metaphysical philosophy still took man as its point of departure, and made his ideas, his convenience, the law of all things. What was to him inconceivable could have no existence; the operations of the universe must take place in the manner which to him appeared simplest. This principle came to a head in that monster fallacy, called, by logicians, the "*sufficient reason.*" A thing must take place in such a manner, must have such or such properties, because we can see no reason why it should be otherwise. That human self-conceit could blind even the piercing intellect of a Leibnitz to the absurdity of this principle, should be to all men a solemn warning. The metaphysical philosophy introduced analysis; it was no longer satisfied with a few poetical generalities on the nature and origin of the universe. It introduced, to a certain extent, observation and experiment, and no longer expected supernatural revelations, or hoped to extend the boundaries of knowledge by spells and incantations. But its analysis was imperfect; it extended not to things in themselves, but to our notions of them, or the words by which they are designated. As if, by studying the name of an object, we could learn its properties, or acquire any knowledge beyond that possessed by its first sponsors. Observation and experiment were employed, but in a very subordinate degree, and their results had often to give place to brain-spun fictions.

We are now in a condition to state the general law of the development of science. It must pass, as we have seen, through three successive stages—the supernatural (personifying or mystical), the metaphysical, and the positive. In the last only does it attain perfection, and assume its due social importance. A few remarks will be needful to throw light upon this great law of philosophic evolution, and to guard against misunderstanding. If we arrange the primary sciences according to the universality and the simplicity of the phenomena which they embrace, we obtain the following series:—Mathematics, astronomy, physics, chemistry, physiology, psychology, and sociology. The same series points out the chronological order in which the sciences arrive at perfection. One by one they detach themselves from the universal "wisdom" of the primitive world, acquire a definite constitution, and are committed to the hands of a distinct order of cultivators. The advance of the simpler sciences not only originates at an earlier date, but is also carried on with greater rapidity. Thus, in an age, in a country, or even in the mind of an individual thinker, we find these great fundamental branches of knowledge arrived at very different states of perfection. Mathematics and astronomy may have reached a high degree of perfection, whilst physics and chemistry are still in the metaphysical epoch, and physiology, psychology, and sociology, entangled in a personifying supernaturalism. No distinct and tangible boundary can be drawn between these three great epochs; we are led from one to another by imperceptible transitions, and do not recognize the change until it has surrounded us on all sides. Neither is the progress of philosophy in general, or of any single science, uniform and constant in its speed. Periods of successful activity are followed, not unfrequently, by a retardation or even a temporary pause. Now one science, and now another, engages the attention of the learned. Sometimes men are engaged with original discovery, and sometimes with the practical application of what is already known. The progress of the

intellect, or, it might be said, of civilization, is, therefore, a highly complicated movement, of which we can form just ideas only by taking a broad and expansive view. Were it a uniform and regular motion, like that of the heavenly bodies, it might be recognized by all. But we may rather liken it to a river: here the current is swift, and there slow; now we come upon a pool, to all appearance stagnant, and now we find an eddy, where floating bodies for a time revolve and return to their former places. Lastly, we sometimes find, *in shallow water*,* a back current, which seems to be reascending to the fountain whence it came. Yet, with all these exceptions and irregularities, the river hurries onward. Whether, as might be concluded from a survey of the last ten centuries, the average advance of the intellect is continually accelerated like that of a body rushing towards the sun, we have not as yet the means of determining.

As to the condition of the arts in the primitive epoch, there prevails the greatest obscurity. Here, however, belongs the invention of many of the most important instruments and tools of daily life, concerning whose origin history is silent. To this period belong the domestication of animals,† the cultivation of the most important vegetable esculents—which may almost be regarded as artificial products—the extraction and working of metals, the use of the common mechanical powers, wheel-carriages, the plough, the loom, the arts of dyeing, calico-printing, the manufacture of glass, navigation, and hieroglyphical writing. This important and valuable list of inventions must not, however, misguide us concerning the intellectual condition of the period. Their arts were strictly empirical, depending upon rules, not principles, and were concealed with the most jealous care. In obedience with the system of castes, every trade or manufacture was the monopoly of some family or tribe, in which its secrets were hereditary. That such a system, however it might for a time foster the rudiments of art, could not but ultimately prove a fatal barrier, will in the present day need little demonstration. The natural aptitude, the inclination for a business, cannot be made hereditary. By the law of caste, all motives which might urge the artisan to aim at higher excellence are for ever excluded. Nay, by a natural tendency of this epoch, the models, the forms, the processes once established, whether in the fine arts or in manufacturing industry, received a kind of religious consecration. To depart from them, even in the way of improvement, was a species of heresy.‡ We must likewise consider the means by which ancient art attained its results, imposing as these doubtless were. Time, labour, human life, were no object. The artificer spent years in carving an urn or embroidering a garment. The monarch, eager to execute some great public work, drove together the inhabitants of a province, and compelled them, at the sword's point, to execute his design. But of this hereafter. We are here naturally led to examine the relation subsisting between science and art—a question upon which there prevails no little obscurity. The very nature of science is commonly misunderstood, not only by the public at large, but even by authors. We frequently see the term applied to pursuits of a frivolous nature, such as fox-hunting, pugilism, &c.; and to others which, however important in their place, have no more right to the name of "science" than to that of religion.‖ A science must be part and parcel of the interpretation of the universe. It is an ever-progressive, consistent, and co-ordinate body of doctrine, deduced from observed phenomena. Whatever does not answer to these characteristics may be art, or it may be erudition, but it is certainly not science. We cannot better point out the distinction between art and science, than in the words of an illustrious writer,§ with whom we have rarely the pleasure of agreeing:—"We mean by science, exact, general, speculative* knowledge. The object of science is *knowledge*, that of art *works*. The latter is satisfied with producing its material results; to the former, the operations of matter, whether natural or artificial, are interesting only so far as they can be embraced by intelligible principles. The end of art is the beginning of science; for when it is seen *what* is done, then comes the question *why* it is done. Art may have fixed general rules stated in words, but she has these merely as means to an end: to science, the propositions which she attains are, each in itself, a sufficient end of the effort by which it is acquired. When art has brought forth her product, her task is finished. Science is constantly led by one step of her path to another. Each proposition which she obtains leads her to go on to other propositions, more general, more profound, more simple. Art puts elements together, without caring to know what they are, or why they coalesce. Science analyzes the compound, and at every such step strives, not only to perform, but to understand, the analysis. Art advances in proportion as she becomes able to bring forth products more multiplied, more complex, and more various; but science, straining her eyes to penetrate more and more deeply into the nature of things, reckons her success in proportion as she sees in all the phenomena, however multiplied, complex, and varied, the results of one or two simple and general laws."

We may add, that the inferior animals are, to a certain degree, capable of art, whilst science is a prerogative of man alone. If we ask whether of the two originated at an earlier period, there is little room for doubt. Art, though not prior in date to that primitive philosophy of which we have been speaking, preceded all exact science, and advanced much more rapidly. The remains of many ancient nations prove that they had made considerable progress in art, whilst of science they appear to have been almost entirely ignorant. Did the builders of ancient Egypt work on scientific principles, when they were astonished at learning from a foreigner the method of ascertaining the height of their own pyramids by means of the shadow? Did science preside over the erection of the Cyclopean remains of southern Italy, of Stonehenge, of the palaces of Nineveh, or the aboriginal mounds and entrenchments of North America? Did the first makers of wine and beer set out from a theory of fermentation? That practice may sometimes outrun theory, is well illustrated in the ingenious process employed in Mexico for extracting silver from its ores. Its inventor, Velasquez, was ignorant of chemistry; nor was it until more than a century had elapsed, that the theory of the process was developed by the united labours of some of the most eminent chemists of the day. But it is maintained that the inventors or improvers of an art must have a tacit, if not an explicit, knowledge of the scientific principles involved. Yes, *tacit*, in very deed. But can that merit the name of a scientific principle, which the supposed possessor is not only unable to impart to others, but of which he is not inwardly self-conscious? Grant this, and the beasts of the field are philosophers; and the ass walking in a straight line towards a cabbage plot, does so from a knowledge of the proposition, that any two sides of a triangle are greater than the third side. Accident, if it never lead, strictly speaking, to *discoveries* in science, may lead to inventions in art. The reason is obvious: the mind of the observer not being duly prepared, apples innumerable might fall from the tree without suggesting any inquiry as to the cause. But no mental preparation is needed for man to repeat an action which, having accidently witnessed, he has found lead to some useful or agreeable result. Primitive man falls into a river, and instinctively clutching at a floating tree trunk, finds himself borne up. Hence may arise an art of navigation, without any knowledge of specific gravities. And, accident apart, repeated trials, conducted in the vaguest manner, may often lead a shrewd observer to valuable results in the arts.

* The Sewells, De Maistres, Romiens, Montalemberts, with retrogressionists, mediævialists, præ-Raphaelites of all kinds, must pardon me this incivility.

† The question has been raised, why the number of tame species has not increased, and what led our forefathers to make such a selection? The probable answer is, that they experimented largely, being impelled by want, and took into their alliance all species capable of domestication. With the exception of the cat, all tame animals are naturally gregarious.

‡ As in China

‖ Such as swimming, horsemanship, and even engineering, navigation, &c An engineer *may* be a man of science, but is not necessarily so; and writers who head advertisements "to engineers, builders, and *other scientific men*," commit a gross absurdity.

§ Whewell. Philosophy of the Inductive Sciences, II., 108.

* The common perverted use of this word, is a fine example of what is called on the continent "English materialism." Speculation originally denoted an abstract study of the universe and its phenomena. We—heaven save the mark!—have dragged it down into the regions of the stock exchange, and apply it to trading operations of hazardous character and equivocal honesty. Compared with this, the "dust of Alexander stopping a bunghole" is a tame joke indeed.

That method of experiment which Bacon condemns as a mere groping, can never lead to the discovery of a new "law of nature," though it may conduct us to a beautiful dyeing ingredient. Yet it must be remembered, processes found out merely in the way of practice without a knowledge of principles, however valuable in themselves, are unfruitful, and can lead us no further. If we would take them for a guide, it is indeed the "blind leading the blind."

As soon, however, as science is constituted, its relation to art becomes closer, and a career of mutual good offices commences, highly favourable to the prosperity of both. Science, on the one hand, interprets the methods which art has hitherto followed in the blind instinct of routine, and leads to their extension and improvement; whilst art repays the light thus received, by supplying science with numberless valuable facts, from which important conclusions may be deduced. How much has chemistry profited by the observations made in the dyehouse, the soap manufactory, the apothecary's workshop, and the forge? Instance the discovery of iodine. A soap-boiler finds in his coppers a corrosive residue of an unknown nature. He puts it in the hands of a scientific chemist, and it proves to be a new elementary body of great importance both to science and art. In the former point of view, it serves to break down an erroneous theory, whilst in the latter it is susceptible of numerous important applications, both in photography and medicine. We may here mention the valuable data furnished to geologists, by the excavations undertaken during the construction of railways, and other engineering operations. We might even say that one cause—and not the least important—why the Greeks and Romans proved unsuccessful in physical science, was their contempt for the practical arts. Hence a vast amount of interesting phenomena entirely escaped their notice. Art is no less exposed to a variety of imperfections, until it has entered into a close relation with science. Not only is its progress much more slow than in subsequent times, but there is great danger of losing what has been already invented. Processes of routine, whose principle is unknown, where an effect is brought about by "rule of thumb," are easily forgotten, more especially if, in the true spirit of mere empirical, unscientific art, they have been kept a secret. Science, by explaining such arbitrary rules, by attaching them to general principles, renders their preservation easy. Many, again, of the most brilliant achievements of modern art would have been impossible without the aid of science. Those improvements in the steam-engine which have immortalized the name of Watt, could not have been undertaken without exact and profound theoretical knowledge. The like may be observed of the safety-lamp, of the recent improvements in dyeing and calico-printing, of the electric telegraph, the electrotype, and all other applications of the galvanic force. The nature of the alliance now subsisting between science and art, is thus admirably stated by Stuart Mill:*—

"Art proposes to itself an end to be attained, defines the end, and hands it over to science. Science receives it, considers it as a phenomena or effect to be studied, and having investigated its causes and conditions, sends it back to art, with a theorem of the combinations of circumstances by which it could be produced. Art then examines these combinations of circumstances, and according as any of them are, or are not, in human power, pronounces the end attainable, or not. Art asserts the end desirable, science lends to art the proposition that the performance of certain actions will attain the end. Art converts the theorem into a rule or precept." Care, however, is needful, as the same author subsequently remarks, that the scientific operation be completed before it is taken as the foundation of a practical rule. Otherwise, if the man of science merely ascertains what circumstances will produce a given result, and neglects to inquire into the action of other contingent circumstances, by which the result may be modified or suspended, his researches will prove of little value to art, and may even bring discredit upon science in the eyes of the vulgar.†

Science, in short, leads to foreknowledge, and foreknowledge to action.* But notwithstanding the capital importance of this relation, it would be forming a very imperfect notion of the sciences, were we to conceive of them merely as forming a base for the arts—a tendency unfortunately too common in our days. Whatever may be the immense services rendered by science to art, although, according to the energetic expression of Bacon, power and knowledge are necessarily proportional, we should never forget that the sciences have, above all, a more direct and more elevated destination, that of satisfying the inherent craving of our intellect to know the laws of phenomena. And if art, on the one hand, has hastened the progress of science, by drawing away our attention from the barren topics of metaphysics to inquiries of an accessible nature, it has, on the other hand, especially since science has approached more nearly to maturity, proved injurious by chaining us down to researches which promise immediate utility, to the neglect of higher speculation. † Art and science, though philosophically connected, are yet distinct, and require distinct cultivators. It would be ill done to leave astronomy to sea captains, physics to engineers, chemistry to druggists; and it is ill done to expect physiology to be successfully advanced by medical men, and sociology by statesmen.

* Logic, II. p. 619.

† By "the vulgar" we denote all persons, of what rank in life soever, who have not undergone a full and harmonious development of their faculties.

* Comte. Philosophie Positive, I. 63.

† Hence the dislike for the practical entertained by the old philosophers, though in the main erroneous, contained a certain portion of truth.

FARRIERY.

CHAPTER III.

ON THE EXTERNAL ANATOMY OF THE HEAD.

PROFILE OF THE HEAD.

PLATE III., FIG. 3.

a a, THE *orbicularis palpibarum muscles.* These surround the eye, and their office is for closing the eyelids. Their situation is within the eyelids, in front of the base of the orbit. They are attached to the orbital portion of the ossa unguis and frontis, to the palpebral ligament, and to the skin of both lids.

b, The *nasalis labii superioris* is situate upon the upper portion of the side of the face. It is of an elongated pyramidal form, with its base turned backwards. Its external surface is convex, and its internal flat. It is attached posteriorly to a slight bony depression at the junction of the superior maxillary and molar bones, a short distance from the lower margin of the orbit of the eye, and, anteriorly, along the middle of the fore-part of the upper lip. Its action is to raise the lip, and dilate the false nostrils.

c, The *dilatator magnus superioris.* Its situation is upon the side of the face, above the zygomaticus muscle. It is broad, thin, elongated, and cleft anteriorly. It is attached behind to the subcutaneous surface of the nasal and frontal bones, reaching as far backwards as the level between the orbital arches; before, by one division, to the lateral parts of the skin of the nose and the false nostrils; by the other division, to the side of the upper lip and angle of the mouth. It lies in a somewhat oblique direction, from behind forwards, inclining downwards. Its action is to assist in the retraction of the upper lip and angle of the mouth, and in the dilatation of both the true and false nostrils.

d, The *dilatator naris lateralis.* This is the dilatator of the side of the nostrils. It is represented in a reversed state, to expose the vessels and nerves which it covers. It is situate upon the side of the face. It is of a flat, pyramidal form, with its base presented forwards. It is attached behind to the fore-end of the zigoma, and to the superior maxilla, for a short space in front of it, before it spreads upon the side of the nostril, and the superio-lateral portion of the upper lip. Its direction is horizontal, divergent as it proceeds forwards. Its office is to dilate the nostrils, and retract the upper lip.

e, The *zygomaticus.* It extends along the middle of the side of the face, from the zygomatic arch and the masseter in front, to the corner of the mouth, clothing the masseter before its fibres grow faint, and imperceptibly disappears in approach-

Fig 1

Fig. 3

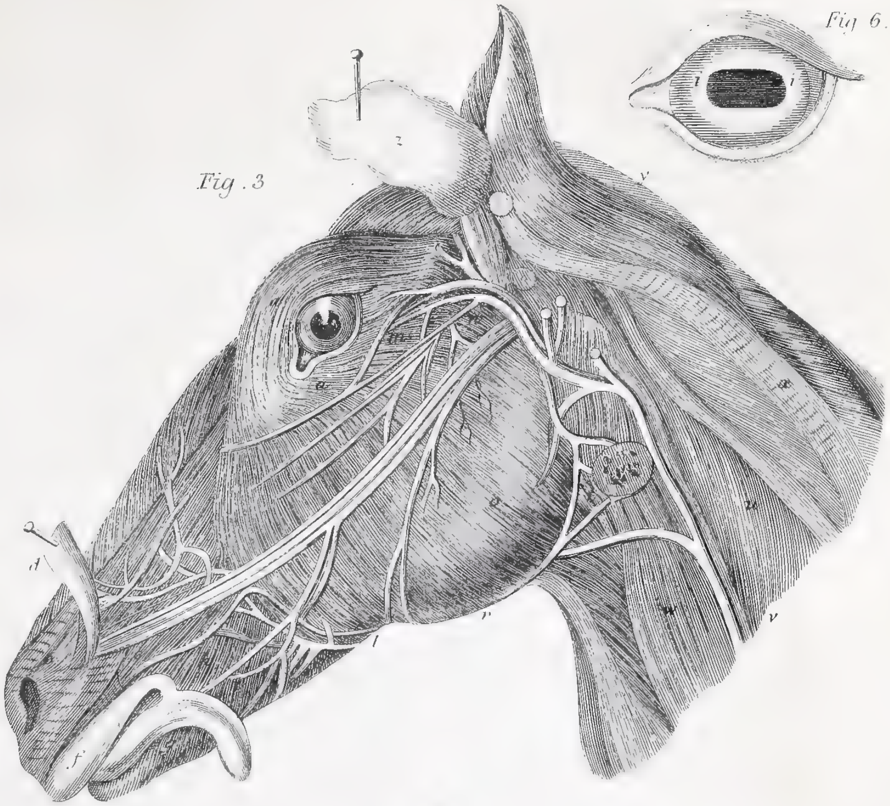


Fig 6.

Fig. 2

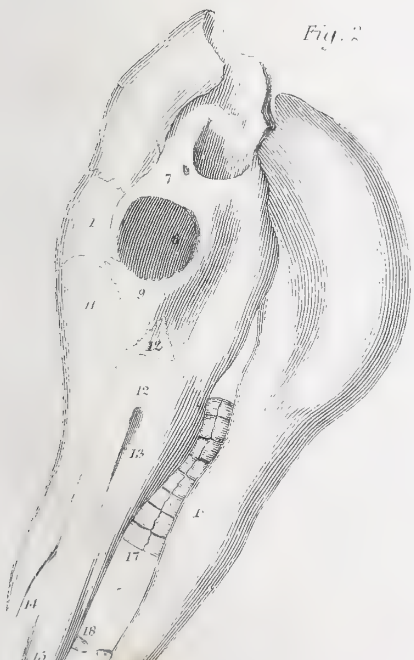


Fig. 4.

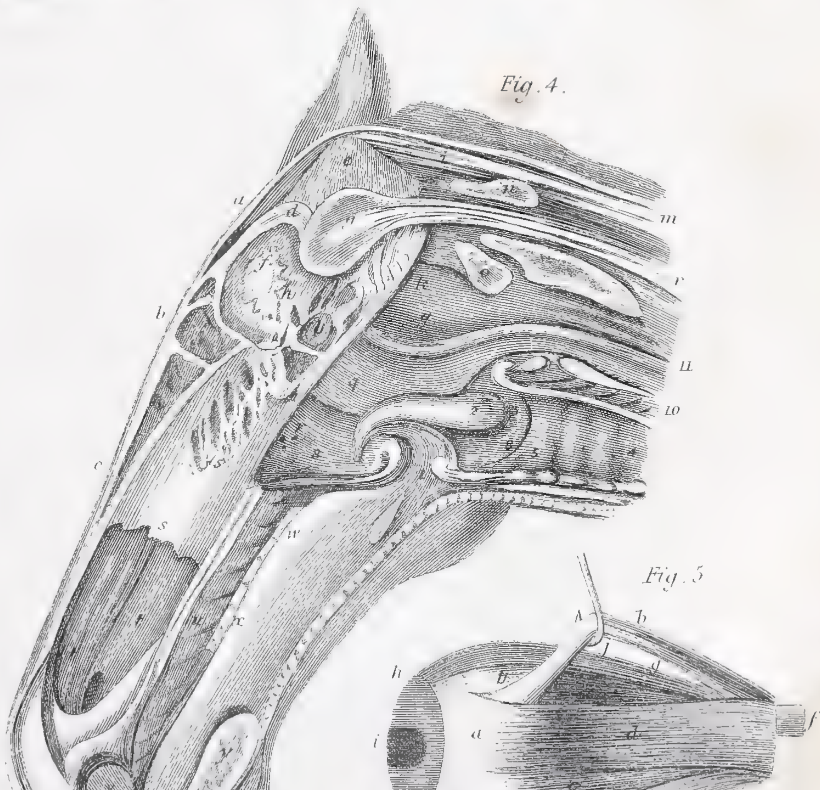


Fig. 5

T. Brown del^t. J. W. Lowry sc.

ing the angle of the mouth; its direction is horizontal, from behind forwards. Its action is to assist in drawing back the angle of the mouth.

f g, The *orbicularis oris*, or circular muscle of the mouth. It is situate within the border of the lips, constituting their chief thickness. Its form is a double semi-ovate, directed backwards, and united at the commissures of the lips. It is attached to the glandular substance and the skin of the lips, more especially at the commissures, where the fibres emanating from both lips cross one another, and become a portion of those of the other muscles contiguous to them. Its office is to bring the lips together, and likewise to assist in the dilatation of the nostrils.

h, The *buccinator*, or trumpeter muscle. Its situation is in the space between the jaws, extending from the inside of the mouth and cheeks to the angle of the mouth, and is posteriorly attached to the border of the lower jaw, in the space between the last molar tooth, and the root of the coronoid process, and the tuberosity of the superior maxilla, above and below, to the outer walls of the alveolar cavities for the molar teeth, anteriorly to the angle of the mouth, and internally to the buccal membrane. Its action is to aid in tightening the buccal membrane, and pull back the angle of the mouth.

i, The *depressor labii inferioris*—the puller down of the lower lip. It is situate along the side of the lower jaw. It is attached behind to the buccinator, with which it blends, and to the tuberosity of the superior maxilla, and the upper border of the lower maxilla, behind its alveoli; in front with the lower lateral portion of the interior of the lower lip. Its office is to pull down the lower lip.

j, Branches of nerves, with small blood-vessels.

k, The *parotid duct*, penetrating the cheek, to discharge the saliva into the mouth. It takes its name from being connected with the parotid gland, which is situate near the ear, and lies within a hollow space at the upper and back part of the head, bounded by the branch of the lower jaw in front, and the petrous portion of the temporal bone behind. The duct emanates from the lower part of the gland, and runs along the inner part of the angle of the jaw, crosses over the hinder edge of the bone immediately above or behind the submaxillary artery and vein. In the rest of its course it corresponds to the border of the masseter, and, nearly opposite to the second front molar tooth, passes obliquely through the buccinator, and terminates by a tubercular eminence upon the internal surface of the buccal membrane.

There are other two glands connected with the salivary system; viz., the *submaxillary* and the *sublingual*. Their use is to secrete a salt clear fluid, which is termed saliva. This is conveyed and poured by their ducts into the mouth during manducation, where it is mixed with the food, softening it, and rendering it more easy of digestion, at the same time facilitating its passage into the stomach.

l, This letter is connected with the explanation of *r*, to which refer.

m, The artery and vein which pass under the zigomatic arch.

n, A branch of the fifth pair of nerves, being the sensitive nerve of the face, which passes from under the parotid gland.

o, The *masseter muscle;* or that which gives the action of chewing. This forms the prominence of the cheek. Its form is thick, broad, and subovate; its upper and front sides form nearly straight lines; its lower back border is curvilinear. It is attached above to the whole of the zygomatic ridge, and the lower border of the arch, extending as far back as the mastoid process; and below to the roughened border which surrounds the angle of the jaw, and to the contiguous parts of the external surface. This muscle occupies the whole cheek of the horse. It is very powerful, and extends from the upper jawbone into the rough surface which embraces the angle of the lower jaw. Its office, in conjunction with the temporal muscle, is to close the mouth, and chew the food.

p, The *stylo-maxillaries*, or *styloid*. It is situated behind the lower jaw. Its form is pyramidal, and its base is turned downwards and forwards. It is attached above and behind to the styloid process of the occipital bone; and below and in front, to the angle of the lower jaw. Its action is to draw the jaw backward, and at the same time to depress it. Consequently, it assists in opening the mouth, and so far is an antagonist to the temporalis and masseter muscles.

q, The *maxillary gland*, or gland of the lower jaw, with its duct.

r, At this point the submaxillary artery, a branch of the jugular artery, and the parotid duct, pass below and within the angle of the lower jaw, and again emanate at *l*, and, ascending the cheek, spread in many branches all over it.

s, The *sub-scapular hyoides*. This is a continuation of the levator humeri, and is spread over the fore and upper parts of the neck. It is in the form of a broad, thin, elongated band, thicker and broader before than behind. It is attached, in connection with the levator humeri, to the inner surface of the scapula, or shoulder-blade; and before, to the middle of the os hyoides. The scapular end consists of a thin flattened tendon, and the remaining portion is fleshy, and altogether forms a kind of fleshy involucrum, or sheath, for the scalenus muscle, which is situate in the lower back part of the neck. Its office is to draw the os hyoides downwards and backwards.

t w, The *sterno-maxillaries*, which is situate in the lower part of the neck. It is of a somewhat cylindrical form, and elongated, flattened both above and below. It is attached behind to the cariniform cartilage of the sternum, or breastbone; and before, to the angle of the lower jaw. It is related externally with the cellular faschia of the neck, panniculus, and levator humeri; and internally, with the sterno-thyrohyoideus, trachea, and carotid artery; along its upper margin, with the jugular vein; along its lower border (the back half), with its fellow, from which it gradually diverges to the head, leaving the trachea and next muscle exposed in the interspace formed by the divergence. Its tendon passes between the parotid and submaxillary glands. It is longitudinal in form, and curving with the neck. Its action is to bend the head towards the breast. Should one muscle act alone, it will, at the time of this inflection, incline the head to one side. The pair will also assist in opening the mouth.

u, The *levator humeri*. It is situated before and below, and lateral parts of the neck. It is of an elongated, flattened form, broadest and thickest at its back and lower parts. It is attached, above and in front, to the tubercle of the occiput, to the mastoid process of the temporal bone, to the transverse process of the atlas, and those of the second, third, and fourth cervical vertebræ; laterally, from the ligamentum nuchæ and faschia, covering the side of the neck; below and behind, slightly to the head of the humerus, to the scapular faschia, to the muscles contiguous to the points of the shoulder; and lastly, to a ridge upon the body of the humerus, which arises from its greater tubercle. The jugular vein extends along its lower front border, and is covered by it for three-fourths of its length downwards. Its front lower margin is thin and expanded, and clips inward, forming a thin fleshy partition between the carotid artery and the jugular vein. Its action is to raise the shoulder and arm, and at the same time draw them forwards; or, these parts being fixed, to turn the neck and head also to one side; or should both act, under such circumstances the head will be depressed.

v, The *jugular vein*. This is the chief venous conduit from the head along the neck, corresponding in course and ramification to the carotid. Consequently, there are two; namely, a *right* and a *left* jugular vein, and it matters little which are described. The jugular vein assumes its formation at the foramen lacerum, at the basis of the head, from the termination there of the lateral sinews of the dura mater, from which it receives the blood returned principally from the cerebellum. At its origin, it is concealed by the condyle of the jaw, and descends to the inner side and behind the neck of the condyle, and is deeply inserted under the parotid gland; lower down, it makes its appearance behind the branch of the lower jaw, where it joins the external carotid artery, along with which it prolongs its passage into the neck. In this portion of its course, it receives the following branches, which are of importance:—1st, The anterior, posterior, and likewise the internal auricular veins, which vary in their number and form of termination, and can be traced descending along the base of

the ear. 2nd, The temporal vein, which is of considerable size, running along the upper side of the temporal artery. 3rd, The internal maxillary vein, which is of large dimensions, and associated with its artery, and in its course receiving numerous small veins. 4th, The parotideal, numerous veins from the parotid; and some, likewise, from the submaxillary gland. 5th, Branches from the masseter and pterygoid muscles, &c. &c. In diseases of the head, neck, and contiguous parts, it is from the jugular vein that blood is taken.

x, The tendon common to the complexus major, or large complicated muscle, and the splenius, or splint-like muscle, and the mastoid process of the temporal muscle. The complexus major is deeply seated underneath the splenius. The action of the complexus is forcibly to erect the head, and have the effect of protruding the nose; or, going beyond this, it will conduce to that appearance called the *oval neck*, in which circumstance it co-operates with the splenius. When the complexus major and the splenius act together, they erect the head and neck; but when either acts by itself, it inclines these parts to one side.

y, The superior portion of the ligament of the neck.

z, The upper portion of the parotid gland. This is situate near the ear, and is reversed, to show the blood-vessels and nerves which lie beneath it.

THE EYE OF THE HORSE, ITS MUSCLES AND OTHER PARTS.

The field of vision, or range of light, in the horse, is very great, surpassing, in this respect, many other quadrupeds. The eye can be moved in all directions by means of seven muscles. Likewise, to give quickness and power of action, it is provided with six nerves. To prevent injury or exhaustion from the constant and rapid friction, the eyeball is seated on a considerable mass of fatty matter; and by the aid of this cushion, it can be moved with ease, and little stress to the muscles. Four of these muscles are straight (see Plate III., figs. 5 a^a, b^b, c^c, *d*). These have their origin in the back of the orbit, and are inserted into the eyeball immediately opposite, and at equal distances from, each other. *a*, The levator, which turns the sight of the eyeball upwards; *b*, the depressor, downwards; *c*, the abductor, outwards; and *d*, the adductor, inwards. All these four muscles, acting simultaneously, will draw the ball backwards, within the orbit. The combined action of any two of them will give the sight an oblique or intermediate direction. These muscles can rotate or turn the eye in any direction which the animal wishes. If the upper and outer muscles are called into action, the horse looks upward and outward; and more upward than outward, in proportion to the degree the upper muscle acts, at the will of the animal, more powerfully than the outer; and thus, by the action of one of them, or the combined action of any two, the eye may be immediately and accurately directed to every point. These muscles, likewise, keep the eye in its place. In the ordinary position of the head of the horse, they must, to a certain extent, be employed for this purpose. When the animal is grazing, the eyes must chiefly be sustained by these muscles; and as, from the frequency and length of time the horse is employed in feeding, they might become fatigued, another muscle is added, called the retractor (or drawer-back), *c*, *c*. It takes its rise from the edge of the foramen, or orifice through which the optic nerve enters the orbit—(Plate III., figs. 1 and 2; 7, 7, 7)—surrounds the nerve in its progress forward, and afterwards partially dividing into four parts, is attached to the back part, or bottom, of the eye. Its office is to give general support to the eye, or, when called into vigorous action, and with the aid of the straight muscles, it draws the eye back, out of the reach of any impending danger; and in the act of drawing back, causes the haw to advance, as an additional defence.

This muscle is endowed with very great power, and it has been found, in attempted operations for cataract, to exert a force equal to more than twenty pounds; consequently, it is nearly impossible to perform an operation on the eye. This is a wise provision for defending the eye from many injuries. Being partly separated into four divisions, it acts as an assistant to the straight muscles in turning the eye. In short, these muscles have several functions attached to them; for, besides what we have above stated, they have still a more important office to perform. Supposing we examine near and distant objects through a telescope, we have to alter the focus, that is, we must increase or diminish the length of the tube. In the examination of distant objects, we must shorten it a little; because the rays, flowing from them to us in a less divergent direction, are sooner brought to a point by the power of the lens; by which the straight and retractor muscles draw back the eye, which forces it towards the substance behind; this in a slight degree flattens it, and brings the lens nearer the retina, and, consequently, adapts the eye to the more perfect discrimination of distant objects.

These muscles being employed in sustaining the height of the eye, they might not be able to turn it so quickly and so extensively, as the animal might wish or require; therefore, two other muscles are given, whose entire use is in turning the eye. They are denominated oblique muscles, from their lying obliquely across the ball of the eye. The conformation of the upper one is singular in its construction, *b*, *b*. It emanates from the back part of the orbit, and proceeds upwards and towards the inner side; and thence, immediately under the ridge of the orbit, it passes through a perfect mechanical pulley; and, turning round, takes a course across the eye, and is inserted somewhat beyond the middle of it, towards the outer side. Consequently, the ball of the eye is evidently directed inward and upward. This is not all, for this remarkable mechanism has yet another end to accomplish. The eye is naturally deep-seated in the socket, that it may be more securely defended; but circumstances may render it necessary occasionally to raise the eye, and thus enlarge the field of vision. Fear has a natural tendency to protrude the eye, as also to occasion the eyelids to open more widely than under a quiescent state, and the eye is forced more forward. It will be asked, How is this possible? There are no muscles before the eyeball, nor indeed any place for their insertion. The object, however, is readily effected by the remarkable pulley, *b j*. By the power of this muscle, the *trochlearis*, or pulley-muscle, and the straight muscles, at the same time, offering no opposition to it, or only regulating the direction of the eye, it is in reality brought somewhat forward. The lower oblique muscle takes its rise immediately within the lachrymal bone (Plate III., fig. 1, *g*, *g*), and, proceeding across the eye, is fixed into that part of the sclerotica, opposite to the other oblique muscle; and so it turns the eye in an opposite direction, at the same time assisting the upper oblique muscle in bringing the eye forward from its socket.

The horse has no eyebrows, and the eyelashes are peculiar in their arrangement. In the upper lid, the rows of cilia, or hairs, are longer and more numerous, particularly towards the temporal or outer corner, because the light comes from above; and those of the lower lid are thin and short, because only a small quantity of light can enter from below. But while grazing, to prevent the annoyance of insects to the eye, towards its inner angle, the only hair is found on the lower lid. Some grooms are so foolish as to cut off the eyelashes, to give the animal, what they think, a neater appearance, thus exposing him to the full blaze of noon-day sun, and depriving him of these valuable appendages for warding off insects. Besides, it has the effect of injuring vision, and has often been the cause of accidents, when the horse is progressing with the sun in his face, and the light dazzling the eyes.

The parts connected with the eye are twofold; namely, those comprehended under the sense of vision, and its muscular structure; or, in more definite terms, the eyeball and its appendages.

The appendages are the eyelids, the eyelashes, the muscles of the eyelids, the tarsal cartilages, the meibomian glands, the tunica conjunctiva, the membrana nictitans, the lachrymal gland, the caruncula lachrymalis, the puncta lachrymalis, the lachrymal sac, the *ductus ad nasum*, and the muscles of the eyeball.

The Eyebrows.—The horse, and all other quadrupeds, are destitute of the supercilium, or eyebrow, which beautiful appendage is found in man alone. But although, strictly speak-

ing, the horse is divested of eyebrows, yet the elevations which form a part of the orbital processes have a similar relation to the eyes, to what the same portions have in man; and these protrusions, in addition to their downy coverings, are provided with numerous long hairs, which, although irregularly placed, are directed downwards in a sloping form, are disposed in arches, and are evidently destined for intercepting strong rays of light, and obstructing, in a certain degree, the passage of dust, or other matters, from falling upon the eye.

The Eyelids.—There are two of them, an upper and lower. Both are retractive and expansive. The upper one, in particular, in the ordinary state, is drawn into wrinkles, which are disposed in curves, and give a peculiar expression to the eye. From these, a pretty good idea may be formed of the age of a horse, as in old ones they are more strongly marked than in young animals. The lower eyelid is provided with six or seven irregularly arranged hairs, of considerable length. These, it is supposed, are destined, as sentinels, to give warning of any impending danger to the eye; for if, by chance, any of them are touched by an insect, or other foreign body, the eyelids are thrown involuntarily into a rapid convulsive twinkle, such as nearly to a certainty will shield the eye from the impingement of such body.

The Eyelashes.—These are much longer, and more regular in their disposition, in the upper than in the lower eyelid. In the upper lid, they grow thin towards the upper canthus, and become gradually fewer, and eventually disappear altogether. In the lower lid, the same arrangement takes place as they approach the lower canthus. This arrangement is admirably adapted for the purpose intended, as, from the position of the head, it is evident, that light coming from above must impinge upon the temple, while that which is reflected from the ground will be directed to the nasal canthus; and thus the eyelashes are suitably disposed to intercept the rays of light in either direction.

Structure of the Eyelids.—The skin covering the eyelids is thin, fine, soft, and very elastic in its texture, and becomes thinner as it approaches the border in which are situate the eyelashes.

The *orbicularis palpebarium* is situate within the eyelids, in front of the base of the orbit. In form, it is obliquely oval, slit in its long diameter. It is attached to the orbital portion of the ossa unguis and frontis, to the palpebral ligament, and to the skin of both lids. Its office is to approximate, or shut, the eyelids.

The Tarsal Cartilages are for giving firmness and elasticity to the margins of the lids. The stiffening of these proves the means of preserving the arrangement of the eyelashes, for without it the hairs would be apt to run across one another.

The Ciliary, or Meibomian Glands, are arranged along the borders of the lids, within grooves adapted for their reception. These are small white follicular bodies, whose canals are large enough to admit of a pin, vertically ranged in parallel lines, like the pipes of an organ. These are quite visible, when the lids are turned inside out, through the thin lining membrane. They secrete an unctuous matter, a sort of oil, which may be squeezed out from the mouths of their ducts—the *ciliary orifices*—in taper portions, resembling small white worms. The use of this secretion is to prevent the lids from being agglutinated, or gummed together, by the mucilaginous matter contained in the tears.

The Cellular Tissue.—These several textures above described, including the *lining membrane* (described below), are all connected together by a fine cellular tissue, completely free from fat; which would prove burdensome and inconvenient to motion, and, by accumulating, would inevitably and permanently close up the eyelids. This does occasionally happen from serous effusion, to which they are particularly liable from their loose contexture.

The Tunica Conjunctiva is the membrane which lines the lids, and from them is reflected upon the eyeball—hence the term *conjunctiva.* This entirely lines both eyelids to their extreme edges. It likewise covers the nictitating membrane, the caruncula lachrymalis, and puncta lachrymalia, and from these it is reflected upon the globe of the eye, and even covers the back portion of it. It is transparent, and the colour of the parts below is transmitted through it. It is particularly liable to inflammation; and when in that state the eyelids become extremely red, and the vessels of the white portion of the eye become gorged with blood, so much so, in many instances, that it appears a solid mass of blood, which extends to the cornea, and renders it opaque and cloudy; so that the vision is rendered imperfect. The conjunctiva is liable to various diseases, and the seat of that violent chronic inflammation which becomes incurable, and frequently terminates in total blindness.

Many farriers suppose that inflammation of the conjunctiva is likewise an index of inflammation in other parts, or, at all events, of the general fever which may accompany local inflammation. Hence it is very common to examine the state of the conjunctiva, by turning down the lid to ascertain the extent of inflammation. But a better criterion of general inflammatory disturbance, especially if the lungs are affected, and one more readily got at, is the membrane lining the nose. If the edge of the nostril be raised, the colour of the nostril will, with a greater degree of certainty, indicate the extent of affections of the chest, and general inflammation and fever.

Use of the Eyelids.—The eye may be compared to a window, and the lids to its shutters, their uses being to exclude light, and defend the eye from accidental injuries. When the lids are shut, the usual apparatus are placed in a state of repose, by the exclusion of light, which is its natural excitant. Consequently, the vision recruits those energies which become exhausted from long-continued exercise. It is for this reason that they are closed during sleep. However, this is not absolutely necessary, for it only requires the suspension of the nervous excitability to put the organ in a complete state of repose. It is well known that many human beings sleep with their eyes open. Winking not only refreshes the eye, but likewise keeps the ball completely free from extraneous substances injuring it.

The Membrana Nictitans.—This is a cartilaginous substance, situate behind the lower canthus, between the eyeball and the side of the orbit; it is vulgarly termed *the haw.* It is only in a perfectly healthy state that the cuticular margin of this substance is naturally visible, and that the line of the transparent cornea is preserved; but, in a morbid state of sensibility, it is forced forward, and encroaches in a greater or smaller degree on the transparent portion of the eye.

Use.—Some comparative anatomists consider this body as a third eyelid. There is little doubt but it answers that purpose in some quadrupeds, and likewise performs the same office in birds. Besides this, it acts in a manner which the eyelids could not accomplish, at least not with the same effect and ease. If the hand is elevated to strike a horse in the face, it will be noticed that a spasmodic twinkle of the lids is accompanied by the instantaneous sliding of the nictitating membrane over the eyeball, to shield the eye from the effect of a blow. But it has a more important office to perform, for which the eyelids are not so well adapted; namely, to dislodge dust, or any small object which may happen to be blown into the eye, thus answering the purpose of hands in man.

The Lachrymal Gland.—This cannot be seen without removing the orbital arch. It is situate underneath this process of bone. The use of this gland is to secrete the tears, which by its ducts are conveyed and spread over the surface of the conjunctiva, where they become diffused over the transparent portion of the eye, washing it from all impurities.

When the lachrymal fluid is secreted in large quantity, it is called *tears.* This is an indication of some irritation in the organ, and inflammation in some of its parts. If it runs down the cheek, it may be suspected that all is not right, and the eye ought to be carefully examined. Even without any foreign substance getting into the eye, this fluid is indispensable to vision, as the transparency would otherwise be destroyed by the atmospheric action inducing evaporation. When dust, insects, or other foreign bodies, are thus wiped off the eye, they are conducted by the tears to the duct, and irritate and obstruct it, or accumulate at the inner angle of the eye, where they are no sooner collected than they are carried off.

There is concealed within the inner corner of the eye, close by the margin of it, a pied, black-mottled, triangular-formed cartilage, called the *haw*, with its broadest part in front. At the will of the animal, this is suddenly forced forward from its concealment, passes rapidly over the eye, and forces before it every impurity mixed with the tears; and by being speedily drawn back, the insect or dust is wiped off as the cartilage again passes under the corner of the eye: this beautiful contrivance supplying the place of the human hand.

The LACHRYMAL CARUNCLE is a small black or pied tubercle, lodged within the inferior canthus, in the space between the eyelids and eyeball. It seems to serve the mechanical purpose of directing the tears into the puncta lachrymalia, as they flow against it along the triangular canal at the lower part of the nose.

A short distance within the nostril, on the division of the nostrils, the lower opening of this canal can be seen; and it ought to be attentively observed and studied, because many have mistaken it for a glanderous ulcer, and excellent horses have frequently been sacrificed from the ignorance of those who have noticed it. Its situation is just where the skin of the muzzle terminates, and the membrane of the nostril commences. This low position is because the nasal membrane is very delicate, and would be irritated, and become a sore, by the constant discharge of the fluid.

This canal is rarely obstructed in the horse, which is fortunate, as the only mode of cure is by placing a style or pin, penetrating into the duct, and it would be quite impossible to keep these in their situation. The ulcer forms in consequence of the distention of the reservoir. The dog is likewise liable to this obstruction of the canal, in which case an ulcer is formed by the sac bursting, which never can be healed.

THE LACHRYMAL PUNCTA AND CONDUITS.—These are two small circular holes, sufficiently large to admit of the end of a common silver probe, and pierce the inward margin of the two lids near the root of the caruncle: they are the outlets of the two little canals already named.

The *lachrymal conduits* are formed within the surface of the lids.

The LACHRYMAL SAC is a small membranous bag, situate within the funnel-shaped bony hollow, which leads into the canal in the lachrymal bone. It is the reservoir into which the tears flow from the lachrymal conduits, and from which they are pressed in the action of winking into the *ductus ad nasum*.

The *ductus ad nasum* is a long membranous canal, commencing from the contracted bottom of the lachrymal sac, terminating at the inner and lower part of the nostrils, and is visible at all times when the nostril is dilated. Its office is to prevent the tears from dropping upon, and irritating, the membrane of the nose. The use of the membrane composing the ducts is to conduct away the tears which are collected within the sac, and to discharge them within the external nostrils. When the tears overflow their proper channel and trickle down the side of the face, the eye is said to be watery; this state often indicates the approach of ophthalmia, and it otherwise accompanies mechanical irritation.

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER X.

To delineate the "plate," half of which is fully given in fig. 70, draw two lines, *a b*, *c d*, at right angles to each other; from fig. 70 take half of the distance, *c d*, and set it off from the point in the copy where the two lines intersect, as *b*, on both sides of *a b* to *c d*. From *c*, with the distance, *c s*, fig. 70, set off to *s*; from *s* draw a line parallel to *c d*; and from *d* a line, *d g*, parallel to *a b*; the outline of the parallelogram will thus be obtained. Find by trial the centres of the circles, *e f*; take from fig. 70 the distances, *s e*, *c f*, and transfer them to the line, *c s*, in the copy; from these points, *e f*, describe semicircles. With the radius, *v s*, or *s t*, from the points, *s*, *c*, *d*, and *g*, in the copy, describe arcs, as *o o*; take from the diagram half the distance between *v* and *t*, and lay this on both sides of the diagonals, joining the opposite extremities of the parallelogram, as *d s*, *c g*; as from the point *n* to *o o*; from the points, *c*, *d*, *g*, and *s*, draw lines through *o*, meeting in the points, as *p*; the centres of the semicircles are described on these lines.

We now proceed to give examples of the methods of delineation of cams, eccentrics, spirals, irregular figures, and the various curves, as the cycloid, &c., useful in mechanics and engineering.

To delineate the "cam," given in fig. 71, the first operation is to find, by trial, the centres of the arcs or portions of circles forming the outline of the diagram; these will be found at *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*. Draw two diameters in the circle, *a*. These preliminary operations being gone through, draw two lines intersecting each other, as at *a′*, fig. 72; continue line, as *m a*; and at *m′* draw a line parallel to *a′*. From the diagram, fig. 71, take the distance, *a b*, and from *a′*, fig. 72, describe an arc to *b′*; from fig. 71 take the distance, *m b*, and from *m′*, in fig. 72, describe another arc, cutting that described from *a′* in *b′*; the point of intersection is the centre corresponding to *b*, fig. 71. From fig. 71 take the distances, *m c*, *a c*, and from *m′ a′*, in fig. 72, describe arcs cutting in the point, *c′*—this is the centre corresponding to *c* in fig. 70. From fig. 71 take the distances, *a f*, *c f*, and from *a′ c′*, with these describe arcs cutting in *f′*. From *a m*, fig. 71, take the distances, *a d*, *m d*, and from *a′* and *m′* describe arcs cutting in *d′*. From *m d*, take the distances, *m e*, *d e*, and from *m′ d′* describe arcs meeting in *e′*. From *a b* take distances, *a h*, *b h*, and from *a′ b′* describe arcs meeting in *h′*. From fig. 71 take distances, *b g*, *a g*, and from *a′ b′*, fig. 72, describe arcs cutting in *g′*. All the centres will thus be found, and positions relative to the point, *a*, corresponding to those found in fig. 71. From the points, *b′ a′*, describe the arcs or portion of circles, the radii of which will be found from fig. 72; then join these by the arc described from the centre, *e′*. From *a′* describe the circles as in the diagram. Describe the arc from *c′*, and join this with the arc described from *h′*; join these by the arc described from the point, *f′*, with that described from *d′*. The double line, as given in fig. 71, is obtained by describing arcs from the same centres as already pointed out, but of less radii—these being finally joined by an arc described from the centre, *g′*.

To delineate the "cam" in fig. 73, as in fig. 74, find all the centres of the arcs or portions of circles constituting the figure; these will be found at *a*, *b*, *c*, *d*, and *e*; draw two diameters in the circle, *a*; and in fig. 74 draw two lines corresponding to these. From *o*, *a*, fig. 73, take the distances, *a b*, *o b*; from *o′ a′*, fig. 74, describe with these arcs cutting in *b′*; continue the diameters, *o a*, *o′ a′*, to *s s′*; measure *a s*, and make *a′ s′* equal to it. From *s a*, take the distances, *s d*, *a d*; and from *a′ s′*, fig. 74, describe arcs cutting in *d′*. From *a d*, fig. 73, take the distances, *a p*, *d p*, and from *a′ d′*, fig. 74, describe arcs cutting in *e′*. From the centre, *a*, take the distance, *a c*, in the diameter, *a c′*, and set it off from *a′* to *c′*. From *a′*, with *a m*, describe the arc *m n*; from *c′*, with *c′ s′*, describe *s′ t*; from *b′*, describe an arc joining this with the circle primarily described from *a′*. From *e′*, describe the arc, *o′ v*, and from *d*, join this with another, *v m*.

To delineate the "cam" in fig. 77, draw the two diameters in the circle, *a*. Find the centres of the various arcs as *b*, *c c*, *d d*, *e e*, and *g* and *h*. Draw the two lines in fig. 78, and describe the circle, *a*. Through *a* extend the diameter; from *a* measure to *c c*, and from *a*, fig. 78, measure on each side, *a f* to the points *c c*. From fig. 77 take the distances, *a d*, *m d*, (*m* is at the upper extremity of the diameter, *a m*), and from *a m*, fig. 78, describe arcs on both sides of the line *m f*, to *d d*. Take the distances, *d e*, *a e*, fig. 77, and from *d a* describe the arcs cutting in *e e*. From *c c* describe the semicircles *c c*, fig. 77; join these with arcs described from *a*, meeting the lines drawn parallel to *m f*, from the extremities of the arcs *g h*. From *e e*, with *e o*, describe arcs cutting in *f*. From *d d* describe the arcs *o s*, and join these by the arc described from *b′*. Finish as in fig. 77.

MECHANICAL DRAWING

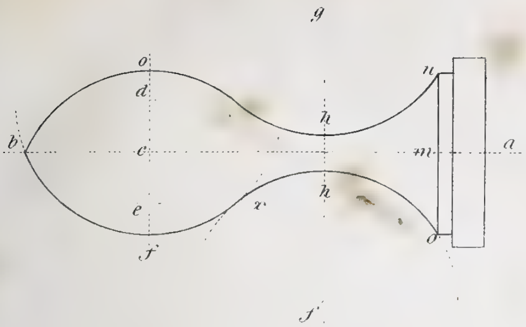
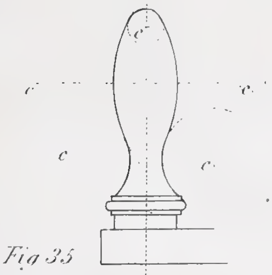


Fig 34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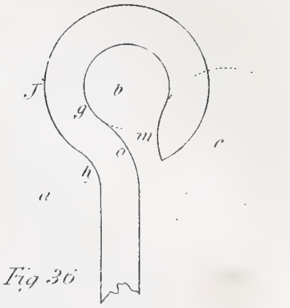
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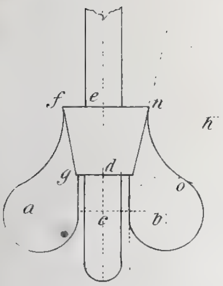
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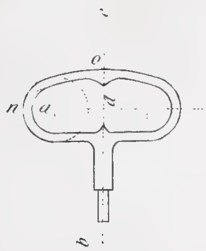
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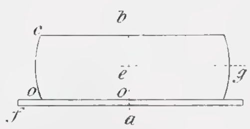
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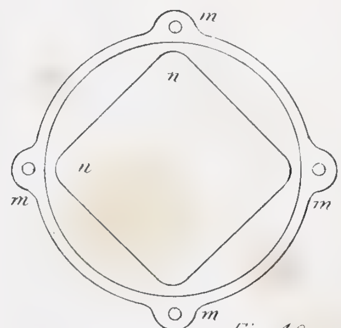
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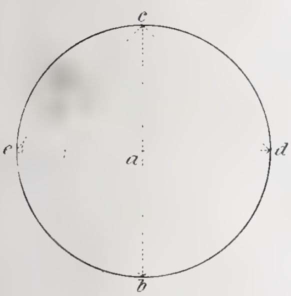
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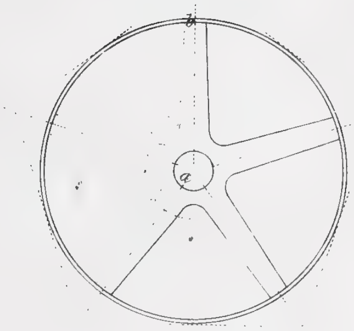
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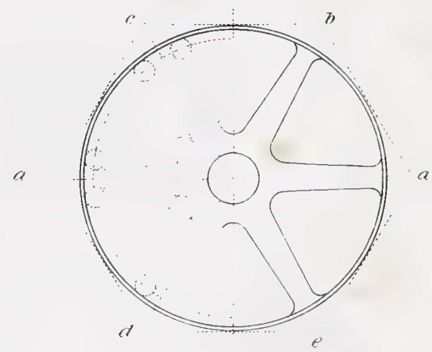
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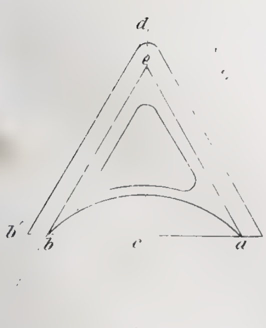
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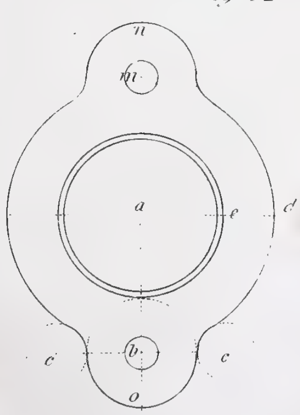
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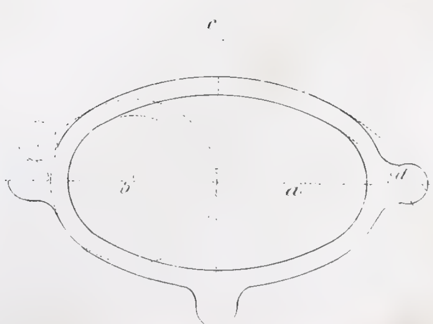


Fig 46

MECHANICAL DRAWING

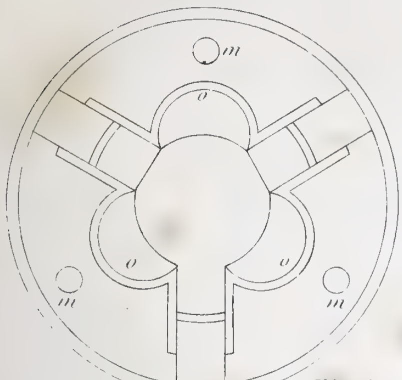
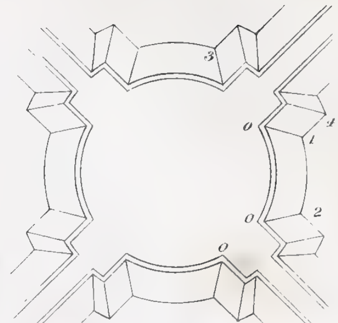


Fig 47

Fig 48



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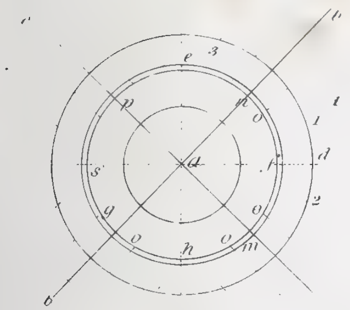


Fig 50

Fig 51

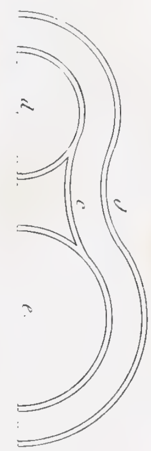
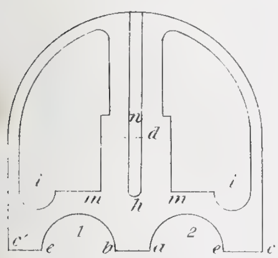


Fig 52



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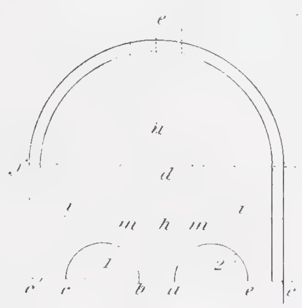


Fig 54

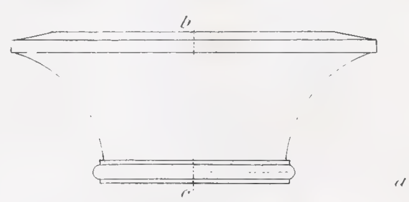


Fig 55

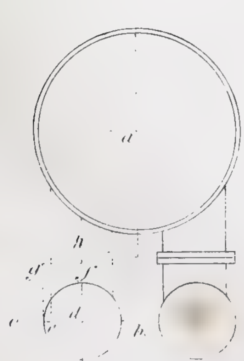


Fig 56

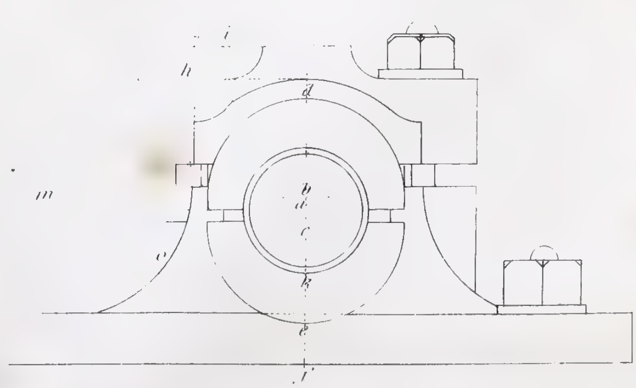


Fig 57

LECTURES ON ARCHITECTURE.

LECTURE V.

THE BEAUTIFUL AND SUBLIME — RULES OF VITRUVIUS — ADVICE TO STUDENTS — CONCLUSION.

THE *αναλογία* of the Greeks, delivered to us by Vitruvius—that analogy by which all the conformations of artificial bodies were derived from natural bodies, is a principle of obvious importance and utility to the architect, and should be attentively considered.

The animal kingdom furnishes clearer lights for our guidance than the vegetable, because organized nature is more constant in her proportions, and enables us always to re-establish the whole from a part; thus the hand of a Grecian statue, of the Hercules, the Apollo, or of the Venus, or a fragment of any one of the Grecian orders of Architecture, enables us to restore the whole; indeed, the proportion by aliquot parts, by a modulus, a principle of the Greeks, as explained by Vitruvius, (lib. i. c. 11; lib. iii. c. 1,) is still practised in India, and seems founded in organized nature.

Not so in the productions of the vegetable kingdom, fragments of which would never enable us to comprehend the whole. However indebted to this part of the creation for the graces of ornament, and various essential analogies, Architecture found a less sure guide of proportion in this than in the animal kingdom: in fact, all architecture so derived is anomalous, as the Egyptian and the Gothic, in which no fixed laws of proportion have ever been applied or attempted. Columns or supports might be from five to fifty diameters in height, and are only bounded by possibility. The stunted pollard, the spreading cedar of Lebanon, the aspiring poplar, or the attenuated cane, are extremes equally at the disposal of the architect.

But that guide which the face of nature furnished to the architect for his external forms and proportions, was wanting for the internal—as of areas, squares, courts, and open places; or of internal capacities (height as well as area); as of temples, halls, apartments, &c.; in these we must appeal to the relations of reason, purpose, and convention.

Vitruvius (lib. vi. c. 2, 3, 4, 6; lib. v. c. 1, and c. 2,) gives us the experience of the ancients on this important subject. The Greek forum, says he, was a square, but the Roman was 3 by 2, because the gladiatorial shows were exhibited there; courts should have the proportions of 5 by 3 (the favourite of the learned Palladio), sometimes 3 by 2, or sesquialteral, or the diagonal of the square will be the length. He lays down the proportions of all the apartments of the Greek and Roman house: atria, alæ, tablinium, and peristylium, triclinia, œci, exedræ & pinacothecæ. He does not, however, establish any *principle,* and his rules are wholly empirical. But the great Alberti, not content without a principle, adopts the Pythagorean doctrine of universal harmony, and agreement between sounds and numbers, namely, that what pleases the ear pleases also the eye; he lays down, therefore, his harmonic proportion, in which Blondel, Ouvrard, and others have followed him. The notion of musical proportions is common, and has occupied many ingenious minds already versed in that art. Describing St. Peter's, Byron, in this feeling, observes—

> Vastness which grows, but grows to *harmonize,*
> All *musical* in its immensities.

Alberti was the first also to establish the rules of arithmetical and geometrical proportions (lib. ix. c. 3, 4, 5, 6), applied to all the varieties of areas and capacities. He is followed by Palladio in the arithmetical and geometrical rules, (lib. i. c. 23.)

It is a comfortable conclusion to the practical architect that the empirical rules of Vitruvius, the harmonic, the geometrical and arithmetical rules of Alberti and his followers, agree in the main; so that either may be adopted without material deviation from correctness; but the neglect of these rules, in which lie that hidden charm that every one must be sensible of when examining a finely proportioned room, has been common of late years, as if the principle were of no value; the zealous student, therefore, should carefully note that consent of the ancients and the most illustrious masters of the moderns, here set forth; and he will soon learn devoutly to repeat the denunciation of the Hindu Vitruvius (Ram Raz, Asiatic Society, 1834, p. 15), "Wo to them who dwell in a house not built according to the proportions of symmetry."

It is true, that the climate of this country and our habits do not often permit the finer Italian proportions; thus the arithmetical rule of proportion, common with our greatest masters, in our best mansions, 36 by 24, should give us 30 feet high to the vault, but we commonly limit it to 18 feet. To correct the defect of lowness, so frequent with us, the illusions of perspective painting, after the admirable Pozzo, may well apply; but even the arrangement of the trabeation and plaster enrichments, offer to the ingenious architect, versed in perspective, many resources for the increase of the apparent height, and for the attainment of an artificial proportion. But a manufacturing people are prone to carpets, rugs, curtains, gilded frames, and mahogany furniture, while the low ceiling is a sheet of paper stretched like a drum, at most of a neutral tint, of indurated fog, with a gilt moulding: again, the artistic Italian opens a window of perspective in his ceiling, through which a canopy of poetry and distance delights the eye, and deceives the understanding; but the floor is paved with tiles.

Further, in our modern churches, a ceiling, 60 by 80, has often been fearlessly stretched in one unbroken surface of plaster, in defiance of the fine examples of Charles' and Queen Anne's churches, in which a cove, after the Italian manner, has the effect of reducing the ceiling, and of rectifying the proportion in the simplest and most graceful manner. The student should well reflect on this important field for architectural skill and effect. He may be a good builder and cheap, but he can have no pretensions as an artist who throws away his time and his character in such condescensions as this mechanical employment of his talent implies.

The rules hitherto referred to, have the beautiful for their object. Beauty in Architecture depends, amongst other causes, especially on the exact and graceful proportions of the parts and of the whole. But the sublime depends upon other causes, in which rules cannot prescribe; to the latter not only the rules of the former do not apply, but they are destructive of it. If the beautiful resides in the proportionate, it would appear that the sublime often resides in the disproportionate. The principles and the rules of beauty and sublimity are distinct. If we stand under an arch of London Bridge, the vaulted soffite, so vast and extended, sustained from such distant abutments, produces a kind of sublime; no doubt aided by its comparative lowness. The Pantheon is inscribed in a cube, its height equal to its diameter; no one standing under its prodigious cupola has ever denied its sublimity. But when that same Pantheon is raised into the air (in equal dimension) at St Peter's, it may have become beautiful, but has lost its quality of sublime. When Byron apostrophizes the Pantheon, he feels the peculiarity of its merit:—

> Simple, erect, severe, austere, sublime,
> Shrine of all saints, and temple of all gods,
> From Jove to Jesus, spared and blest by Time,
> Looking tranquillity!

As the dome of the Pantheon is raised at St Peter's into a proportionate height, at the expense of its sublime, so the nave (nearly twice as wide as that of St Paul's Cathedral), also raised proportionately, loses all effect of magnitude; and the common and universal observation is, that, as respects this important effect, the architect has laboured in vain; and the work stands self-condemned.

The noble poet coincides with the received opinion, and is obliged to supply, by poetical moonshine, that dignity and interest which it was his object to give to the Vatican. He says—

> Enter, its grandeur overwhelms you not,
> And why? it is not lessened; but thy mind,
> Expanded by the genius of the spot,
> Has grown colossal; and can only find
> A fit abode wherein appear enshrined,
> Thy hopes of immortality!

Sometimes this failure has been attributed to its proportion, which (from its justness, it is said) takes from its magnitude; a criticism at once the most severe and just that can be. In fact, no increase of a proportionate object will ever give it magnitude and the sublime; these depend on extraordinary relations and excess of parts and proportions.

Some years ago a French giant, upwards of nine feet high, exhibited himself in London; but so just were his proportions that no one would give credit to his dimension, till they stood beside him; he was therefore accounted a kind of fraud, and the exhibition failed. But had he been disproportioned, his head

small, his shoulders high, and his members excessive, he might have succeeded, even had he been a foot shorter. Had the nave of St Peter's, 77 feet wide, been 90 feet high only, instead of 145; or if we were to suppose a stage raised mid-height, and place ourselves upon it, we should be sensible of its vast latitude, and the effect of magnitude would have been produced as under a bridge. The Barrière de l'Etoile, from the same reasons, though as large as the front of Notre Dame—the arch itself 48 by 95, equal to the height of the nave, but of ordinary proportions and great simplicity of parts and members—loses its effect: the *arc monstre* is glorious to the *grande armée*, but not to the arts of their day; and it is infinitely less artificial in its combination than the arches of St Martin and St Antoine, designed by the accomplished Blondel.

If, then, the architect can obtain latitude, he should seek to carry out its effect by quadrate and comparatively low proportions; but if he adds altitude to his latitude, he loses his expense and pains, and he may find too late that half his dimension might have attained the same effect; since *proportionate magnitude* defeats itself.

But as extreme latitude gives the sublime, so does its opposite extreme of altitude. In Cologne and Beauvais, the naves of which are three and a half diameters in height, though scarcely more than half the actual width of St Peter's nave—limited, therefore, in their dimension to the usual cathedral width, yet nearly double the usual proportion—the sublime is completely attained; and disproportion again appears to be the efficient cause.

But the optical consideration of the visual angle in which these proportions present themselves is exceedingly important. Thus, to the spectator of the dome of the Pantheon, the visual angle is 95°, while the same dome raised into the air at St. Peter's is only 30°, In the nave of St. Peter's the visual angle is 48°, that of St. Paul's cathedral is 37°, while the vault of Cologne is only 22°. Since, then, the effect of magnitude is measured by the number of degrees in the visual angle, the architect will advert to this consideration as of extreme interest.

We come, then, to the important conclusion that the sublime and the beautiful are to be found in the proper adjustment of proportions, rather than in dimensions; and we may infer, that no increase of scale to the beautiful will ever make it the sublime.

But the sublime is of rare occurrence: the use, however, to which these reflections may be turned by the practical architect, under limited means, is remarkably illustrated in the Casino at Chiswick, where the very circumscribed area of the rooms is compensated by their extraordinary height; and the accomplished Lord Burlington has given a nobility to very small apartments which no one could believe on seeing the plan alone, without visiting that elegant work.

Magnitude is the great object and result of design, and this quality is only to be attained by the fine adjustment of relative proportions in magnitude and order. Architecture (says Aristotle) consists in magnitude and order, (τὸ γὰρ καλὸν ἐν μεγέθει καὶ τάξει ἐστι.) The works of man, compared with those of Nature, display our insignificance. The Pyramids, seen in the clear sky of Egypt, or St Peter's at Rome, are proverbially disappointing to the first gaze of the beholder: it is only after he has instituted comparisons and admeasurements that he becomes sensible of the greatness of these human efforts,—and his memory will supply him with many instances in which objects of very inferior dimensions have surpassed them in impression of magnitude upon his mind. It is plain, therefore, that Art alone can produce the full effect of magnitude, and to this the architect should direct all his skill: the ancients will be found consummate masters in this as well as in every other department of our art. It is, indeed, a fine art which enables the accomplished artist to raise ideas of magnitude and grandeur of composition on a piece of paper no bigger than your hand, while a less able one shall cover a vast canvas without executing any comparable notions. Worthy of all inquiry and solicitude is such an art, for it is the whole art of design and proportion. Pliny cites a statue of Hercules, so small that it might be lifted by the hand, which, however, conveyed more grandeur, magnitude, and strength, to the mind of the observer, than a Colossus would have done. How great must have been the science of the master; and if, with such small means, and on, comparatively, so insignificant a scale, he could affect the mind with those impressions, how great the economy of cost and material to the employer!

Burke, whose notions, however, of proportion are vague and erroneous, says admirably on this point (sec. x.)—" A true artist should put a generous deceit on the spectators, and effect the noblest designs by easy methods. Designs which are vast only by their dimensions, are always the sign of a common and low imagination."

In the last lecture it was attempted to show that magnitude, breadth, and proportion of parts were best found in inequalities; but the consideration of magnitude, as respects composition of the whole, seems to depend on other principles: first, it appears that, to make a great whole, there must be many parts; secondly, to appreciate that whole, the point from which it is permitted to be seen should be eusynoptic; namely, so contrived as to fill the angle of vision of 45°, and occupy the whole retina with multiplied impressions fairly and agreeably presented.

With reference to the first proposition, it may be observed, that in a young tree bursting from the ground, two or three branches with upward tendency grow from the polished bark; the subdivisions are few, and we may count the leaves. By and by, with age and maturity, the bark becomes rough and corrugated, the base is surrounded with excrescences and roots, which, partly above the ground, indicate the hold it has on all the surrounding space; the branches now shoot out at right angles with the bulky stem, each limb becomes a tree, the subdivisions of these are infinite, and, in all degrees of size and proportion, the leaves are countless. So the young animal, simple in parts, and smooth, expanding with age and strength, develops features and subordinate parts never dreamt of before; furnished and complete, the measure and fulness of strength and beauty are at length filled up. So in Architecture, the tetra-style portico can never look large, though, in St Peter's, the columns have eight feet in diameter. The Hecatompedon, burnt by the Persians, was not inferior in the scale of its parts to the present Parthenon; but Ictinus judged that, by increasing the number of parts —making that octo-style which had been hexa-style only—greater magnificence would result.

The temple of the Giants, at Agrigentum (hepta-style), was the largest Doric of antiquity; but to give it all its value, a number of new features, never seen before, accompany its increased growth and vastness. It is raised on a platform of many steps, a base of novel design surrounds the columns, and these vast masses themselves, each a tower of thirteen feet in diameter, built of *many* stones, told by its *many parts* and its elaborate construction the cost and grandeur of the undertaking. So the columns at Pœstum have twenty-four instead of the usual twenty flutings: in short, examples are infinite to show that, to convey the full effect of real magnitude, an artificial magnitude must be superadded, or it is lost labour.

Gradation and repetition of features of the same general resemblance in various sizes, the major and the minor, are main sources of magnitude; the artist will see in the satellites surrounding the planet Jupiter, the best reason for the title of the Father of the gods; the western towers of St Paul's give magnitude to the dome. The same principle was to have been applied to St Peter's, but the western towers fell down. In the admirable church of the Salute at Venice, the minor dome over the high altar, and again the still smaller domes accompanying this, are foils to the great dome. Byron admirably enforces the number of parts:—

> "Thou seest not all; but piecemeal thou must break,
> To separate contemplation the great whole;
> And as the ocean many bays will make,
> That ask the eye—so here condense thy soul
> To more immediate objects, and control
> Thy thoughts, until thy mind hath got by heart
> Its eloquent proportions, and unroll
> In mighty graduations, part by part,
> The glory which at once upon thee did not dart."
>
> *Childe Harold*, c. iv. v. 157.

So Palladio (as already remarked) characterized his style by the inter-penetration of the larger order by a smaller.

In decoration we are careful to put a small scroll in juxtaposition to the larger, to give its full effect; and so the painter to give size to his principal figures, interposes women and children in various gradations: the wreath or swag which shall contain flowers or fruit all of the same size, will be mean, or look like a string of onions; the whole secret of proportion and whole purpose of magnificence is attained by satellites, and by gradation of the major and the minor.

With reference to the second proposition, the consideration of the point of view of architectural works, the ancients, as has been already observed, were consummate masters, and cannot be too carefully studied. The labour of the architect is vain if he miscalculates the point of view, and the picture which he is to present on the retina of the spectator. As well might the painter consent to a bad light for his work, as the architect be careless on this vital point. The *genius loci* will insist upon a peculiar composition; each position requires its own adaptation; we should have proper things in proper places. A design good in one place may fail in another, and the unskilful approach and point of view may ruin the best scheme. It is not enough to be right, but to show that you are so: the "*faire valoir*," is a fine economy which runs through the architecture of life, as well as of every step in brick and mortar. The architect must be well versed in this part of optics: the synoptic, the eusynoptic, the *deceptio visus*, should be his constant observation; like a skilful general he must manage and manœuvre his masses to impose upon the spectator; and, by their skilful disposition he may often gain that ascendancy which his real forces may not warrant. A familiar instance of this is seen at St Paul's, and often practised upon the green-horn mason, who visits London for the first time. Of the two orders which decorate the exterior, the lower one forms the great order of the interior, in the same precise dimension; but the angle of view in the interior being so much larger, the spectator is persuaded of its larger dimension. The roguish cicerone engages the novice in a dispute on this question, enforced by a bet, which on proof is always to his disadvantage and the penalty of his pot of beer.

Sometimes accident does more for us than wit. St Paul's, constrained and crowded amidst narrow streets, produces on the unsophisticated a magnitude and interest which would be lost if the pedants had their way, and large areas and terraces were to expose it from Farringdon Street and the Thames.

While considering magnitude, we must not forget that (the most difficult of all) which arises from greatness of conception—a quality which every one habituated to contemplate fine buildings, must often have been impressed with. But much more the ingenious architect, who in his practice has had opportunities of comparing his own design with those of others more able than himself, and still more in canvassing the various modes in which a work might be performed, will remark the difference between one mind and another. He will find all the moral qualities of the artist exhibited in his performance. "By their works ye shall know them;" greatness of soul, or contractedness of spirit, a folly or a vice, the specious, the clumsy, the refined, the honest, are written in characters quite legible to those who have learned to decipher the language of design.

We might show the character of Wren in the lineaments of his work—sublime in his mathematical attainments; clear, original and comprehensive in his combinations above all men; but in his exterior unobtrusive and timid, small and elaborate, concealing the art (as Nature does), revealed only on our nearer examination to our wonder and delight. We plainly see "the Nestor of Athens, not only in his profession the greatest man of that age, but who had given more proof of it than any other man ever did; he was in a manner the inventor of the use of mechanical powers; and they record of him that he was so prodigiously exact, that, for experiment's sake, he built an edifice of great beauty, and seeming strength, but so contrived as to bear only its own weight,—so that it fell with no other pressure than the settling of a *Wren!* But such was Nestor's modesty, that his art and skill were soon disregarded, for want of that manner with which men of the world support and assert the merit of their own performances: and for want of that natural freedom and audacity, necessary in the commerce of life, his personal modesty overthrew all his public actions,"—Parentalia, p. 341.

In the works of Jones we see the beautiful and specious, the sensual beauty of the tasteful artist, but no mathematics, no sublime combinations of structure; but generous, and free, and highly ornamental, we discover the director of the masques of the splendid court of the Stuarts,—the "Marquis Would-be."

In Vanbrugh we have the dramatist throughout; his theatre and scenery are everywhere imposing with a pompous grandiose; the spectator is at first captivated, till he peeps behind the scene, and the illusion vanishes.

In short, it is plain that the architect must have moral as well as intellectual qualities, in order to acquit himself duly of the high charge intrusted to him; and no argument can more effectually convince the student, that in ordering his studies he must first order his own character and conduct; and that nothing can come from him of great and noble, unless from a pure fountain and a well-regulated stream. We must endeavour to sustain that rank in society which both sacred and classical antiquity have assigned to the architect. (See Isaiah, c. iii; v. 1, 2, 3; and Cic. Off. p. 42.)

But an important principle in the æsthetical as well as in the real ends and purposes of our art is solidity, the result of equilibrium between the forces of gravity. Nothing can be beautiful which is not strong, or is not adequately strong for its purpose. The impression of duration is indispensable to that satisfaction and repose which the mind seeks in a well-ordered work of Architecture. According to the simple notions of the ancients, it was the essence of the grandiose and beautiful. The Temple of the Eternal was to breathe the spirit of Eternity;—strong in its entire structure, it was to be strong also in its component parts, its "great stones." Energy, mental and physical, and stability, were the expressions most desired in Architecture; voids were to be above voids, solids above solids; the area even of the supports, and the incumbent weight (orthographically considered) in most instances of the finest temples are, or approach to, equality.

To this end the whole composition of the edifice was pyramidal, the sides being inclined (as has already been observed) in every style of architecture known to us. The quoins and piers of the angles which enclose the work are larger than those towards the centre; and we may be sure that the expression of strength and duration given to a building is often of itself sufficient for beauty, without other adventitious ornament; as we may also be certain that the want of this quality cannot be repaired by any expedient which the architect may apply. In fact, the qualities of solidity and equipoise impose on the understanding the same awe and conviction with reason, justice, and truth; as inspiring that security, stability, and peace, without which all is flimsy conceit and vain ambition.

But this rational propensity is sometimes in jeopardy from the love of the marvellous and the exhibition of skill in the artificer, from whom, while we deprecate the hazard, we cannot withhold our applause; and if assured, either by the nature of the material or the quality of the structure, of the security the mind demands, we are easily reconciled to the wonder. But this temptation is often a severe trial to the ambitious architect; and without a sober taste, chastened by modesty and reason, it may be often more than he can resist.

We delight in the suspended arch of a bridge or in the enormous vault which covers the Pantheon, or the Baths of Caracalla, or the Temple of Peace. We are reconciled to those of the Gothic cathedral, so long as their stone-props or buttresses continue to perform their duty. Not so in the grove at the east end of Salisbury Cathedral, which, like the banyan tree, seems to be composed of pendants from the roof, in different dimensions, rather than columns to support it; beautiful, indeed, but so fragile that the blow of a stick, or the movement of an awkward visitor would put the whole fabric in peril. If, instead of a friable stone or marble, these shafts were made of brass, the mind would relapse into that security which is ever the first requirement of our art.

The love of the marvellous is dangerous: exaggeration is the first sign of a mind indifferent to the value, and beauty, and sufficiency of truth, and the surest sign of depravation of judgment. Truth must ever be the best foundation of taste, and can alone be constant and enduring,—

> Rien n'est beau que le vrai: le vrai seul est aimable!
> Il doit regner partout, et même dans la Fable.
> De toute fiction, l'adroite fausseté,
> Ne tend qu'a faire aux yeux briller la verité.
>
> *Boileau*, Ep. ix. v., 43.

The Egyptian, the Roman, and sometimes the Greek, indulged in the gigantic, with a view to the expression of a prodigious energy. But the Middle Ages were prone to the marvellous; surprise was the great scope of the Gothic architect. Æsthetics were not, indeed, likely to have been studied under the education to which the mind at that time had access. Miracles infatuated the understanding; superstition was the foundation; a dominant hierarchy was but little communicative of the lights of science it possessed. The poetical vein received its chief aliment

from the East; our scholars brought home from Cordova the Arabian taste for excess and hyperbole. The chastening counsel of a Locke, a Newton, or a Bacon, were wanting to regulate that exuberant and uncultured fancy, and that enterprising skill which the practical experiments in building promoted at so much cost and zeal in those ages.

The two styles of building, till the fifteenth century, were termed *more Romano*, in semicircular arches, which followed the old basilica model of St Peter's and St Paul's, and *more Germano*, in which the pointed arch was employed after the thirteenth century: it was in the latter taste that the greatest works were executed.

However great and admirable, in many respects, the specimens which have been left us by those able practitioners, it is not believed by the most competent judges that theoretical science was cultivated to any extent. From Cesare Cesariano, the architect of Milan Cathedral, and one of the earliest translators of Vitruvius, doubtless one of the most learned architects of his day (1524), we may learn something of the principles which guided the Middle Ages, which were full of the mystical terms of the pseudo-science of the Freemasons. They consisted of a series of triangles or pyramids, no doubt in allusion to the triune, which guided the plan, elevation, and section. (See D'Agencourt's Architecture, plate 46, in which the sections of Milan and Bologna cathedrals illustrate those doctrines.) The Minster at Bath appears to have been built after this theory (1503) by Dr Oliver King, who was a skilful architect and politician, and had been employed in France to conclude a peace with Charles VIII., and who, therefore, would be acquainted with the most approved art of that day on the continent.

The Middle Age church was wholly founded on superstitious associations. According to *more Romano*, it was enough that the plan described the cross, the universal "in hoc vince,". But according to *more Germano*, the Saviour himself was to be figured; the choir, therefore, was inclined to the south, to signify that "he bowed his head and gave up the Ghost," (John c. xx. v. 30), and there are few cathedrals in which this deflection is not remarkable. The nave represents the body, and the side, which "one of the soldiers pierced," (John xix. 34), considered to be the south, as the region of the heart, is occupied at Wells by a chantrey, at Winchester with the chapel of William of Wyckham, and is constantly the pulpit from which the faithful were reminded "to look on him whom they have pierced," (Zech. xii. 10:) who "was wounded for our transgressions," (Isa. liii. 5.) For the same reason the south was considered the most holy: the Old Testament was represented on that side, while the New Testament, and the local or national Hagiology, was placed on the north. The same superstition still gives value to the south side of the churchyard for burial. At the head of the cross was the chapel of the Virgin at the Fountain of Intercession with her son. At the foot, the west end, was the "Parvis," supposed by some to be a corruption of "Paradis," that happy station from which the devout might contemplate the glory of the fabric, which was chiefly illustrated in this front and from whence they might scan the great sculptured picture, the calendar for unlearned men, as illustrative of Christian doctrine and of the temporal history of the church under its princes and its prelates. Three great niches leading into the church, the centre one often above forty feet wide, were adorned with the statues of the apostles and holy men, who "marshal us the way that we should go;" in front, the genealogy of Christ, the Final Judgment, the History of the Patriarchs, &c.

The details, indeed, display the degraded state of the Fine Arts, and of course, of the artists themselves, in the quaintness and disproportion of the sculpture. But extending our indulgence to the performers, regarded in illiberal times only as workmen, we shall admire their native genius, struggling with their moral condition, often on the verge of dignity and grace in execution, and in point of conception frequently reaching an elevation altogether original. It must be confessed, that the continental churches, especially those of Amiens, Rheims, and Paris, surpass the magnificence of our own cathedrals, both in the extent of plan by their double aisles, as well as by their height. But it may be questioned whether a more complete and correct picture of Christian doctrine and dispensation, and Christian history, is to be found anywhere than in Wells Cathedral.

But the same want of cultivated judgment which is apparent in the æsthetical of the arts of the middle ages, is traced also in the imperfection of their statics and stereotomy, in which again solidity is sacrificed to superstition. The indispensable figure of the cross is a striking example. The arches of the nave, in the northern basilica, found their abutment abundantly in the western termination, which was commonly fortified by prominent buttresses (called by the early commentators of Vitruvius, tetra-style, or hexa-style, according to their number); but at their eastern termination, towards the lofty pillar of the transept, no such abutment existed. And though the pointed arch was eminently calculated to obviate lateral pressure, yet the smallest failure of foundation or superstructure threw so much weight against these pillars as to occasion them to bend. To counteract this, and secure their stability, the principle of that age, of "pondus addit robur;" namely, the weighting the pillars of the transept with a tower or spire, was resorted to very commonly; but this often increasing the evil, the last disfiguring remedy, the construction of a reversed arch between them, was employed.

Similar criticisms apply to all parts of the middle age Architecture, mixed, however, with redeeming excellencies of peculiar skill hitherto unsurpassed.—See sections 1 to 8 of Wren's Surveys, in the "Parentalia," 264 to 309.

The fifth of those principles of Vitruvius, which the Professor had attempted to illustrate, was Decor, usually considered to refer to that important part of Architecture, ornament; but our author rather appeared to refer to consistency of character, fitness of style and ornament to the Deity, and the purpose or the rank to which the work might be dedicated, quoted in the preceding lecture. But as no part of the art required a nicer judgment, tact, and reasoning, than this of character and special physiognomy, so was none more commonly transgressed in many modern buildings; and a stranger might be conducted to some of them, and defied to guess whether he beheld a library or a town hall, a church or a music-room, a theatre, a prison, a brewhouse, or a floor-cloth manufactory, a gentleman's mansion or a union workhouse.

Appropriateness and fitness of character is the special recommendation of all the great critics, from Aristotle to Pope. If, says Horace, to a horse's neck a human head is joined, or a female head and breast should terminate in a fish, you will despise the painter; or if upon the stage you exhibit the graces and the levities of youth, hashed up with the manly strength of middle life or the rigour of old age, the audience would yawn, and at length overwhelm you with indignant hisses. It is, in fact, the significance and appropriateness resulting from the coincidence of use and beauty, the one the explanation and plain result of the other, which we adore in the works of Nature, and which the great artists have best known how to imitate in theirs.

Sir C. Wren remarks on the Temple of Peace,—"It was not therefore unskilfulness in the architect, that made him choose this flat kind of aspect for his temple; it was his wit and judgment. Each deity had a peculiar gesture, face, and dress, hieroglyphically proper to it; as their stories were but morals involved; and not only their altars and sacrifices were mystical, but the very forms of their temples. No language, no poetry can so describe Peace, and the effects of it in men's minds, as the design of this temple naturally paints it, without any affectation of the allegory. It is easy of access, and open; carries an humble front, but embraces wide; is luminous and pleasant, and content with an internal greatness, despises an invidious appearance of all that height it might otherwise boast of; but rather, fortifying itself on every side, rests secure on a square and ample basis." On the Temple of War, he says, "As studiously as the aspect of the Temple of Peace was contrived in allusion to Peace and its attributes, so is this of Mars appropriated to War: a strong and stately temple shows itself forward; and that it might not lose any of its bulk, a vast wall of near 100 feet high is placed behind it; (because, as Vitruvius notes, things appear less in the open air); and though it be a single wall, erected chiefly to add glory to the fabric, and to muster up at once a terrible front of trophies and statues, which stand here in double ranks, yet an ingenious use is made of it, to obscure two irregular entrances," &c.

The German Moller, who is as true and accomplished an artist as any of modern times, has some remarks on this point of the consistency of a building, not only of its several parts one with another, but of the whole with its great ultimate object or design, which are well worthy our notice, as proving the attention paid to it

in other times. Taking two well-known buildings as examples, he says, "On comparing the elevation of the Merchants' Guildhouse at Mentz with the Church of Oppenheim, which was finished in the same year, we see how anxious the ancients were, and how well they contrived to impart to every building its peculiar character. Just as the merit of historical painting, and of every art of design, (without which all the rest is valueless,) consists in the importance and peculiarity of its character; so they are principal requisites in buildings whenever the latter lay claim to the appellation of works of art. In the church at Oppenheim, all the parts are lightly towering up, so that the eye of the spectator in the interior is involuntarily raised, and the elevated richly ornamented windows, and slender aspiring pillars, promise from the outside already a beautiful and sublime interior. But in the Merchants' Guildhouse, the whole exterior announces at once an object very different from that of a church. The few and small windows are easily closed against fire and robbers; and their battlements again, with their projecting canopies and angular enrichments, clearly show that the destination of the building is to preserve and to protect. And in the same way as the main forms correspond with the object of the structure, so likewise do the ingeniously designed ornaments. On the pinnacles or battlements are the figures of the emperors and electors in full armour. The emperor, who, at that time in alliance with the electors, had confirmed the commercial union of the cities on the Rhine, and taken them under his protection, appears with them here as the guardian and bulwark of the house. In the midst of the princes is the figure of St. Martin, the patron of the city, dividing his cloak with his sword, to give it to the poor. Thus the leading forms announce the destination and solidity of the building: the figures of the princes, the protection it enjoys; St. Martin, that beneficence which ought to be the attendant of wealth; and the Virgin Mary with the infant Jesus over the entrance, the higher safeguard which the Divinity grants only to the *just*." Thus says the accomplished Moller.

It is a fine observation of Aristotle, that "a noble building without ornament is like a healthy man in indigence." Competence, if not wealth, must be added for the accomplishment of his happiness.

The sculptor's art affords the noblest ornaments to the architect. By his aid, the expression which he has been labouring to give by other associations, and which before was mute, or scarcely audible, becomes *parlant*. Sculpture may be called the voice of Architecture. Unhappily a Protestant country, with the holy fear of image-worship, discourages this generous and most essential art; and perhaps the want of character complained of in Architecture may be mainly attributed to this proscription.

But the carver and the decorator are highly serviceable to the architect, not only as multiplying images for the delight of the eye and the explanation of the subject, but as greatly magnifying the scale of the whole by these means, and giving value and distinction to the plainer features. Our mistress Nature is prodigal in ornament, and the expression of every animal and vegetable is increased by a texture of endless detail spread over the whole surface of her works.

Finally, Distributio, the *οἰκονομία* of the Greeks, the sixth principle, is explained by Vitruvius, dryly, as economy in the use and cost of materials; but, doubtless, the great masters from whom he borrowed, considered economy, in the larger sense, as the adjustment of means to the end; as the wise and fine thought, contrivance and supply, of all the requirements and appliances of the building art; in which the highest intelligence is displayed; such, indeed, as by that figure of speech which designates great subjects by small titles, applies to the *Creator* himself that of the Great Architect.

The diligent observer of architectural works will find the greatest strength combined with the least material, beauty united with use, and resulting from it, exact equilibrium, provisions for the accidents of time and climate, selection of materials best adapted; in short, a prescience of every want and consideration: throughout the contrivance admiration almost sublime is occasioned; we feel that the work has, as it were, been self-created by the influences and the wisdom of Nature, and as if the Architect had only followed her instructions. "I am not," says the heifer of Myron, "the work of Myron—he only delivered me from the marble in which I was enclosed."

Having thus reviewed the theoretical rules handed down by Vitruvius from the Greeks, as far as the limits and means permitted, the Professor proceeded to offer some observations to the students with reference to their future advancement, which it was the object of these lectures, and the ardent wish of the members of the Academy, to promote.

First, with respect to drawing, which was the very language of the art, it was extremely important that the main distinction between the painter and the architect should be clearly understood. He deprecated the vain ambition of making pretty drawings, especially on a small scale, as effeminate and uninstructive; as also of pretensions to aërial perspective, which was a separate art. Much time was commonly occupied in this captivating study, which was wholly irrelevant, and at the expense of that valuable time which should be employed in the more essential accomplishments of the art and science. It might, indeed, improve the hand, but not the head; of which the architect had so much need. Drawing, after the manner of painters, had undoubtedly been an abuse and misdirection.

The orthographic drawing or elevation was conventional: it represented the proposed building from an immeasurable distance—the object being to define those proportions and profiles which constitute the merit of the work—such lights and shades as should more clearly display these forms, and show their relief where necessary; but whatever disturbed these paramount objects, as colour, or such cast shades as might confuse the profiles and pretend to illusion, were impertinent.

Perspective, in the most accurate delineation, was, indeed, a most desirable accomplishment; but it should be wholly linear, assisted with one tone, or two at most. Sciography should be used with great reserve, since the harsh outlines of cast shades were apt to disturb the form and outline; and the finest architectural perspectives, those of Pozzo especially, left them softened and undefined on this account. It was certain that such had been the practice of the great Italian masters, specimens of which, by the hands of Sansovino (the front of Sta. Maria, at Florence, in the possession of Mr Woodburn), of Michael Angelo, Raphael, and others, and especially the designs for Whitehall, by Inigo Jones, the Professor had exhibited in a former course. Exquisite perspective, proportion, and profile, were more scientific, difficult, and much more profitable to the student. The coloured picturesque was a pandering to a depraved taste, and it was a duty to inform the public on this head, and lead them to the appreciation of the true intent of architectural delineation. The draftsman should be habituated to a large scale, and a manly drawing of profile and detail, such as a builder would comprehend and work from. The Professor exhibited a specimen of the architectural drawing of the actual school in Paris, which, though not wholly to be approved, as being rather too minute and elaborate in effect, still showed a more careful attention to outline, and a better system than used by ourselves.

The architectural room in the annual exhibition was at great disadvantage in the neighbourhood of the splendours of the sister art; the vain attempt at vying with her productions in architectural drawings, has both corrupted our style and exposed the utter futility of the attempt. The true course would be a closer adherence to the province of the architect in a more correct delineation of profile and proportion, and in the most accurate linear perspective; a tasteful employment of these resources would probably more effectually uphold the interest of that room than any other means that could be devised.

Constant observation and travel were essential to the architect; but the interesting objects of our own country should be seen before those of others. Much time was often lost in foreign travel by misdirection and the dangerous novelty of the student's position.

In examining architectural works, the student should bear in mind an important rule of criticism, which is, to account in precise terms for the motives of approbation or dislike which he might experience. By applying a just expression on all occasions, he would soon cease to take one thing for another—the beautiful for the sublime—quantity for quality—cost for magnificence—and either of these for proportion or fitness—ornament for art. He would learn to apply characteristic terms to every gradation, quality, and style; and so, by degrees, he would form a just and discriminating taste.

In an art and science essentially referrible to association, this discrimination was peculiarly necessary: the emotions arising from sight, like those from music, would often be found irrespective of the intrinsic merit of the performance, as loyalty in hearing "God Save the Queen;" union and patriotism in the "Marseillaise." Often patriotic, historical, and romantic associations will blind us to forms and styles, otherwise both unfit and unworthy of our age; often quantity, extent, and quality of material

would impose that approbation which ought only to be accorded to elegant and just proportions ; elaboration would often usurp the praise which was due only to a well-ordered work:

To hide by ornament the want of art,

should not deceive the experienced critic ; and the painter " who would make his Venus *fine*, not knowing how to make her *beautiful*," would be ranked as he deserved. The discernment of merits rather than defects will be found more difficult, and much more profitable, because those we shall appropriate, while the latter are only to be rejected. Such a habit will exercise the better qualities of the mind, and lead to originality. The works of men who have long enjoyed reputation, should be the peculiar objects of our critical examination ; they will seldom be found frauds ; the inquiry will commonly justify their fame, and like the conversations of original inventors, they will reveal secrets which can else hardly be discovered.

The antiquary should be distinguished from the architect, and we should be careful to separate the available experience from research into the curious and obsolete.

The student was recommended especially to cultivate that manly independence of mind which became a thinker, and the leader of an art ; he should have a settled distrust of fashion ; although he would find himself sometimes constrained in some measure to bend to it. Those "who live to please, must please to live ;" he should, however, courageously but respectfully remonstrate.

There were two errors which the art was expressly liable to : the first was the presumption of absolute novelty ; the second, the indolent and servile imitation of former styles. The latter was the peculiar vice of these times throughout all the civilized countries of Europe. Grecian, Gothic, Byzantine, Italian, Revival, French, were indifferently employed. There was no attempt at a style which should express to future ages the century in which we live ; and posterity will be at a loss to recognise in the buildings of our day, that character which a country great and glorious at the present period, the bulwark of civilization, the arbiter of the world, and the great exemplar of political government, morals, and useful science, should impress upon its architectural productions. Shall it be said that this great people, original and free in other respects, adapting and expanding itself in an unexampled manner to times and improvements, was stationary, or rather retrograde, in the arts alone ?—that though science, and capital, and mechanical skill, were daily furnishing new engines for our arts, with prodigality, that our invention alone in these walks of genius was at a stand ?—that our skill as artists was the only deficiency in the march of our age ?—that they crudely adapted the models of ancient Greece to modern London ; the sunny palaces of Italy to the foggy atmosphere of England ; the niched and canopied architecture of a religion peopled with images of saints and martyrs, sibyls, angels, and holy men, to a Protestant religion, which, admitting none of these, must leave the niches and the canopies *tenantless;* like well-gilt frames adorning an apartment, the *pictures* being omitted : the pride and pomp of heraldry, armorial shields and crests, to an age in which chivalry was exploded, and quarterings had dwindled to insignificance ? What should we say of Harry the Sixth, if, instead of that admirable and most original chapel of King's College, at Cambridge, he had limited his artists to the style of the Conqueror, or any other imitation ; or if Henry the Seventh had concluded on carrying on the style of the cathedral of Henry the Third, and so on, saving all further trouble of invention and criticism, should we not contemn their poverty of spirit and negation of mind ? Would not the historian, the artist, and the tasteful observer, have to deplore the absence of that internal evidence and hieroglyphic character of the times, which adds such a relish to the architectural remains of our fair and beloved country ?

But let us suppose that either of these monarchs had been enlightened by the art of a Raphael or a Michael Angelo, or by the sculptures of a Phidias, which he might even affect to appreciate and to be proud of; and that we should learn by historical record that he had said,—" We are so anxious to carry out the style of former days that we shall shut our eyes to those excellencies of sculpture and of fine art, and force our artists to copy the obscenities and senseless carvings of those barbarous times ; simply that we may carry out the imitation of the style in all respects."

Restoration, indeed, is altogether a different consideration, and the happiest result of this taste is, that we reinstate, for centuries to come, these venerable antiquities to which we have so many reasons of attachment. The restoration of the Palace at Westminster may find under this consideration a sufficient apology. But for works altogether new, such a system of imitation is not reconcileable with our pretensions to genius and enlightenment ; and it does appear that there is in it a vice of mind or of industry for which posterity will visit us. Such an indifference as to choice of styles indicates, in fact, an absence of culture and perception of the really fit, and beautiful, and great,—a state of mind which, in religion, politics, or morals, would be accounted fatal to improvement, and the sure forerunner of every heresy. D'Agencourt attributes to this spirit of imitation, under the emperor Hadrian, the decline of taste in Rome.

The learned in Paris deplore it not only under this apprehension, but as the imposition of anachronisms on posterity, and as the falsification of the pages of history, in its most interesting and characteristic traits. " Have we not," as says Isaiah, " a lie in our right hand ?"

It is very important that the merits of that question should be debated in a candid spirit, and that the true grounds of a style should be investigated by the rules of sound criticism ; as, how far Architecture has ever been and should be the picture in which all the discoveries of mechanics, of materials, and of industry, are to be exhibited and recorded ; and whether the successive changes of style have not been chiefly owing to the progressive discoveries and improvements on workmanship, materials, and convenience,—how far the combinations of this art are capable of displaying the intellectual character of an age and people, and what should be the just bounds and limits of association, authority, and imitation.

Finally, let us never forget the pregnant saying of the great Schiller :—

The artist is the son of his time ;
Happy for him if he is not its pupil ;
And happier still if not its favourite.

In conclusion, the Professor expressed the gratification he had felt in the attention paid by the students to this course of lectures ; not as it reflected upon himself personally, but as it gave the strongest possible evidence of the ardour and assiduity with which they pursued their studies ; for he could with great sincerity assure them that, amongst the achievements of a very long period of singleness and devotion to his profession, he should consider that the most glorious, which had contributed to the instruction, and warmed the enthusiasm, of those rising talents destined, perhaps, in future times to adorn and illustrate our country.

HISTORY.

CHAPTER XXI.

THE MORAL AND INTELLECTUAL CHARACTER OF THE FEUDAL AGE.

It is perhaps scarcely necessary to recall attention to the error of supposing that the dates of the commencement and termination of any historical period are marked by a sudden and abrupt change in the feelings, opinions, and institutions of society. The flow of events is unremitting ; the change of moral phenomena insensible. From 814, of our era, to 1519, we have called the feudal era, because during that period the class of society organized into a kind of corporate body by feudal relations, held, with a few exceptions, the sovereignty over Europe. The attempt to organize a great monarchy over this quarter of the globe broke down upon the death of Charles the Great. The permanent establishment of several independent national governments was cotemporary with the outbreak of the reformation in the Church. But, on the one hand, the feudal system was considerably developed long prior to the time of Charlemagne, and did not arrive at its perfect growth and symmetry until long after his time. And on the other, the great national governments of England, France, and Spain, and the numerous territorial powers in Italy and Germany, subject more in name than in reality to a common head, had struck deep and abiding roots previous to the commencement of the sixteenth century. In attributing to the whole period, from 814 to 1519,

the epithet of the age of feudal institutions, no more is implied than that during that period these institutions were, if not the sole and uncontested, the preponderating secular power.

It is necessary above all things that in endeavouring to estimate the moral and intellectual character of this period, we form correct and definite notions,—first, of the influences which were at work to produce diversity of character among the inhabitants of different territorial sections of Europe; secondly, of the influences that were at work to produce a certain community of interests and a feeling of one common citizenship.

I.—And first, of the influences at work to produce diversity of character. In Italy, the Roman manners, customs, and modes of thought continued to maintain the ascendancy. The Venetians and Romans were races almost free from Teutonic admixture. In the exarchate of Ravenna the Teutonic admixture was very slender, and we have noticed on a former occasion that while in other Germanic kingdoms the Romans were obliged to cede a portion of their lands in property to the invaders in Lombardy, the conquerors seem to have rested content with an annual tribute of a proportion of the fruits. We can trace the endurance of the old municipal institutions in Italy unbroken, uninterrupted, from before the Germanic conquest down to the twelfth and thirteenth centuries. The old Italian language was to that of modern Italy, what the Anglo-Saxon has been to the language we now speak. It furnished by far the greater proportion of vocables, and imposed its laws of construction upon the Germanic words and phrases that were insensibly adopted from the new comers. The restriction of the sway of the Roman empire, after the extinction of Charlemagne's descendants, to Italy and Germany, and the shadowy nature of that sway, kept Italy in a great measure a country apart. The arrangement by which the kings of Naples consented to hold their lands as a fief of the Pope, contributed still further to the territorial separation of Italy from the rest of Europe. Thus circumstanced, the lapse of a few centuries was sufficient to induce a peculiar national character in the Italians. The municipal institutions kept the upper hand in Italy; the vicinity of the seat of church sovereignty gave the Italians opportunities of seeing behind the scenes which led them to reverence the pontiffs less than more remote nations, while at the same time the pride that an Italian priest should rule the rest of the church gave them a partizan feeling in his favour; the old schools of literature were more frequent in Italy than in the provinces, and the remains of ancient art more numerous and perfect; their extending mercantile enterprise brought them into connection with more refined nations.

In Spain, the municipal institutions under the Roman empire were more upon a footing with those of Italy than was the case in Gaul. Of all the Germanic tribes that founded dynasties within the limits of the empire, the Goths had received the deepest tincture of Roman civilization. The pervading medium of communication in Spain among the influential classes was Latin—the conventional Latin of authors, not the indigenous dialects of the provinces. The Goths became in laws and language more thoroughly latinized than any of the other new Germanic settlers. The invasion of the Arabs in the course of the seventh century, by driving back the Gothic-Romans into the hill-lands in the north of Spain, broke up much of the old municipal institutions, and gave a greater preponderancy to the feudal institutions than was the case in Italy. The pressure of the Arabs produced a two-fold effect upon the Goths of Spain. In the first place it kindled in them a partisan spirit of adherence to the Christian faith, less from rational conviction than from pride in it as a badge of distinction between them and the herds with whom they were doomed to wage an exterminating war for the possession of their native valleys. Whatever might be the general state of Spain, there was never peace along the line which marked the frontiers of the Christian and Mussulman territories. It was in Spain that these anomalous mixtures of the ascetic and military spirit, the monastic orders of knighthood, first attained their full stature. The wealth and distinction of these orders attracted the ambitious and enterprising spirits of Spain, and contributed mainly to diffuse throughout the nation a spurious but fascinating modification of Christianity. The second effect produced upon the Gotho-Roman indwellers in Spain by the Saracenic pressure was a comparatively high degree of refinement, learning, and mercantile enterprise. Whatever Mahommed and his nomade Arab tribes might be, the body of the Arabian nation at the moment that his doctrines propelled him upon the Roman empire, were neither a barbarous nor an illiterate race. In the latter history of the Jewish nation we read repeatedly of an Arab kingdom of which the capital was Petra. The ruins of that city, which have been in a manner re-discovered in our day, attest a degree of civilization at least equal to that which is known to have existed in Palmyra, (the capital of a kindred race under Zenobia.) The Greek names of some of the monarchs of Petra point to the hypothesis that it might be the seat of one of those Greek dynasties founded upon the ruins of Alexander's empire. We learn from the later Roman historians that mercantile enterprize flourished from the gulf of Arabia southward along the gulf of the Red Sea. We have no reason to believe that the original Arabic invaders of the territories of the emperors of Byzantium were in civilization materially behind or inferior to the population of the realm they invaded. Once masters of the Greek seats of commerce and learning, they showed themselves apt pupils of the scholars of the age. The splendour and refinement of the court of the Califs at Bagdad is known to all; and the researches of the Alexandrian school were successfully prosecuted by many an Arabic sage. In Spain, the Arabs founded an empire, during the continuance of which their knowledge and refinement continued to increase. An irrefragable proof of this continuous progress may be deduced from a comparison between their architectural remains in Cordova and Grenada. The former date almost from their first establishment, and are heavy and inartificial combinations of the elements of Byzantine architecture. The latter are the elaboration of these elements by ripened taste and genius into an original and peculiar, and highly charming school of architecture. There are sufficient grounds to infer that it was not in architecture alone that the Arabs of Spain continued to make progress. The amenities of life seem to have made equal progress among this elegant and spirited people. The freedom of their women—so discrepant to the customs of their Turkish brethren in faith—has been referred to their intercourse with the Spaniards. This is questionable. The Bedouin woman is comparatively free; it is only among the Mussulman races who have settled in the former Persian and Byzantine dominions that we find the abject slavery and seclusion generally associated in our minds with Mussulman manners. It is from these corrupt courts, not from Mahommed, that the extreme rigidness of the seclusion has been derived. The Arabs, who made their way to Europe, over Syria and Alexandria, knew not of it. That the respect and tender deference to women reached a height in Spain unknown before, not long before the expulsion of the Arabs, is certain; but whether the change took its rise with Christian or Mussulman, or simultaneously with both, it would be difficult to decide. Such was the condition of Arab society in Spain, and it must be remembered that the relation of all Spanish Christians to the Arabs was not a relation of unmitigated and uninterrupted animosity. The Arabs, from the first, allowed considerable privileges to such Christians as chose to remain in the conquered territory. A certain proportion of the churches were reserved to them in other cities. The payment of a capitation tax insured to those abiders in their old heritages immunity and protection. The persecutions of the Christians were few and transient: security was the rule, not the exception. The industry, wealth, and refinement of the Arabs awakened the emulation of the Christians, and when one after another the warrior tribes of Goths who had maintained their independence among the northern hills, re-conquered the outlying provinces of the Arab empire, they found in them a more industrious, skilful, and civilized Christian population than their fathers had left. Nor had the dark spirit of fanaticism which the Inquisition kindled in the breast of subsequent generations of Spaniards been waked previous to the conquest of Granada. Under these different influences a national character came gradually to pervade the whole of Spain.

In Gaul, or as we may henceforth call it France, the municipal institutions had never been so all-pervading as in Italy or even in Spain. Many of the municipalities of Gaul were municipalities more in name than in reality. They were not cities with a surrounding territory; they were several rural villages united into one jurisdiction with the privileges not of an Italian—that is, of a full and perfect—but only of a provincial municipality. The municipalities of Gaul which enjoyed the full municipal privilege were comparatively few, and of those the majority were in the south: as the traveller advanced northwards they disappeared altogether, until he reached the Rhine lands, where a belt of very important municipalities had been planted along the frontiers. At the time of the Teutonic invasion, owing to this circumstance, the original customs and language of the Gauls had beyond the limits of what was called *par excellence* "the province," been less completely obliterated than in Spain. The Celtic dialect continued to predominate in the Aquitaine, and along the western and northern coasts; while the Teutonic predominated in Belgium. Even where the Latin tongue prevailed it was spoken with an intonation, and with peculiarities of structure, some of which remaining to the present day remind us of the Celtic origin of the mass of the people.

The successive inundations of Teutonic tribes which conquered and re-conquered France from each other, the ruder character of these tribes preserved among the governing class more of the Teutonic forms of spirit and modes of thought than ever obtained in Italy or Spain. The later conquests of the Normans upon the north coast increased this peculiarity. Still the municipalities, especially in the south, were sufficiently numerous and influential to give the tone to the language. The predominating ingredient in the French tongue is the Latin, although it was long ere this came to be decided. In Provence the prevailing dialect was long more nearly akin to what was spoken in the neighbouring states of Italy, than French is now to Italian. In the districts along the base of the Pyrenees, a language was spoken (where the Celtic did not predominate), more akin to the Spanish than the French. As men approached the Rhine, dialects of almost pure Teutonic were met with. In the northern districts of France, Aquitaine had been a portion of the Visigothic empire, Provence of the kingdom of the Heruli and Astragoths, and Burgundy had been an independent state. The Norman dukedoms had peculiar institutions, and were held by a proud warrior race. The semi-Celts of Bretagne and the Celts of Bearn had customs and immunities of their own. All these territories, and the minor ones interspersed between them, even while acknowledging a common head, were similarly jealous, and each afraid of being assimilated in its institutions to the other. Hence sprung a jealous assertion of the peculiar franchises of each province; a clinging to established usages which, if detrimental as opposed to progressive amelioration, is, under certain circumstances, useful as teaching men the habit of opposing monarchical self-will. The French, like the Spaniards, saw the Pope from a distance; but they had not their sectarian spirit kindled by constant hostilities with men of an adverse faith. Surrounded by Christian countries, they were not whipped into submission to the common head by incessant attacks from the infidel. Neither had they the feeling of secular partisanship kindled in the Italian breast by the feeling of national prejudice. Of all the churches which have remained in communion with the Roman, the Gallican has ever been the most cool and measured in its allegiance—the most sturdy in the assertion of its rights. Gaul was not like Italy, an old seat of learning; nor was it brought like Spain into immediate collision with the more refined Arabs. Still, in the southern provinces, the twilight of the set learning of the empire lingered on the horizon till the re-ascension of the sun. Something, too, may be attributed to the contagious influence of Spain in the regions of Bordeaux, of Provence, in Italy. The Sorbonne of Paris is, of all the modern European Universities, that which (in the faculties of theology and the arts, at least) can produce the oldest authentic records. That portion of the literature of France, however, which corresponds with the Moorish warfare in Spain, and the predecessors of Dante in Italy, belongs exclusively to the southern provinces. France seems never to have had a popular superstition marked by equally strong national features with that of Italy or Spain.

The territories composing the German empire were more extensive at first: and gradually dwindled away till the time of Francis of Austria. It included Switzerland and the Tyrol, Austria proper, Bavaria, Franconia, Bohemia, Saxony proper, the greater proportion of the territories out of which the kingdom ot Prussia was ultimately erected, the Saxonies, Westphalia, the Baltic provinces, the Netherlands, and territories west of the Rhine, which extended deep into the heart of modern France. From the accession of the Saxon emperors, however, this mighty territory was one state in little more than name. The great princes, lay and civil, in whom ultimately centered the right of election, asserted almost from the beginning unlimited territorial jurisdiction. They elected one of themselves, and although they continued to pay him the feudal forms of vassalage, they stopped there. The large commercial cities were subject to the empire; and there was an infinite number of nobles and men of equestrian rank in the empire, who asserted independence of those territorial magnates, and acknowledged only the sovereignty of the emperor. The efforts, however, of the free towns and the nobility of the empire to repel the encroachments of the territorial dynasts, achieved little more than the perpetuation of a state of disorganization in which every man was obliged to defend himself. The burghers of the free towns of the empire were safe within their own walls: and for their protection beyond them, several cities formed leagues of alliance among themselves. This was the origin of the celebrated Hanseatic league, and of the scarcely less celebrated Suabian league. Each petty owner of a feudal tower with a small surrounding district asserted independence of all except the emperor within his property, and exacted toll and convey-money from all who crossed his fields or sailed under his crag-built tower. Such exactions were rarely repressed by the territorial potentates except when they wished to arrogate the same rights to themselves; and the attempt was the signal for war between the aggressor and the allies of the party attacked. Such a state of affairs was unfavourable to the progress of civilisation, and the mass of the population within the limits of the German empire had among them fewer germs of civilization than any of the nations that have already been enumerated. Roman civilization had never struck root in their soil, Cologne and Mayence on the Rhine, and a few towns along the Danube excepted. Germany was peopled by an unmixed Teutonic race. It was only under the immediate predecessors of Charlemagne that Christianity had been preached in the south of Germany; and it was under Charlemagne that the Saxons and Thuringians were reduced to an imperfect and merely outward conformity by the sword. Between the Rhine and the Elbe, the greater part of the land was an alternation of forest, heath, and morass. The mass of the population were tillers of the soil, living in the south in villages, in the north in isolated and thinly scattered dwellings. The towns founded by emperors of territorial potentates, for the promotion of trade, or as garrisons amid a disaffected peasantry; or which grew up around the residence of a bishop or some wealthy cloister, were the first seats of self-government and its concomitants—regular industry and civilization. But German civilization had in a great measure to begin from the beginning. The Germans did not inherit a language stored with words and forms of expression, the fruit of an advanced civilization and learning; their language had to be civilized as well as themselves. The missionaries in Germany could, even when masters of the language, only speak by analogies between the divine truths of their religion and the rude conceptions of their hearers. They were deficient in the neatness, power of adaptation and self-reliance of more southern nations; but there was about and within them the vigour of young, simple and uncontaminated society. If there was boorishness, there was strength: if there was want of refined sentiment, there was honesty and self-controul.

Till the middle of the eleventh century, England continued in a middle state between the original German constitutions, and the feudal organization. The Saxons and other Germanic tribes had invaded as *fursten* and *deenstgefelge;* but the Britons had in a great measure left the low country vacant for them; and the new comers, until the Normans and Danes commenced their piratical career, had been left without rivals. The lands between the Humber and the Forth seem to have been chiefly peopled by tribes from the low peninsula of Jutland, or the territories north of the Baltic. The Hebrides and the Isle of Man had been subjected by the same race. The transient Danish conquest had left many with Norse blood in their veins. For sometime previous to the invasion of William, many Normans had settled in England. He found a large and by no means uninfluential body in England ready to acknowledge his claims on account of his descent. But the warriors who accompanied him, and who were richly gifted with lands were of those Normans who had been long enough settled in France to acquire the predominant tongue of that land. Down to the time of the first Edward, England continued to be ruled by monarchs who spoke no language but Norman-French. Feudal institutions might be developing themselves in England under the Saxon dynasty: but the full-grown feudalism of England dates from the Norman conquest. The feudal power was vested in the Norman race; but the Saxons were too far advanced to be reduced as the conquered race were in other lands. They were a high-spirited and united race, having among them a nobility of their own, and, even when war or disturbances occurred, claiming concessions. It was not in the municipalities alone that this spirit was found in England: the old Teutonic spirit animated the country constitutions, and they forced their way up through the feudal organization into the government of the country, to an extent unequalled in any other European state. The Norman dynasty subdued, in time, the Celts of Wales and Ireland; and if those of Scotland did not also own their yoke, it was owing to the erection of a kingdom in those northern parts, the main-stay of which was a Norman and Saxon population. The only nation with which Britain, environed in its world of waters, came into collision was France: and the anxiety of the Norman rulers of England to retain their hereditary fiefs on the continent, kept up a series of hostilities between the two countries for centuries, which encouraged in each a sterner and more repulsive nationality. The language of England came in time to be an intermediate grade between the unmixed Teutonic dialects of the empire, and the Romanic languages of the other nations of Europe. It is

Teutonic in the bulk of its vocables, Teutonic in its forms of speech, with a strong admixture of words from the Romanic dialects.

Thus have we seen the spaces of the earth's surface, over which, from the time of the subversion of the western empire, Roman citizens and Teutonic tribes had been mixed among each other, gradually settle without amalgamation under the influence of time, local propinquity or remoteness, and events, into six great nations, with strongly marked and diverse national characters—the Italians, the Spaniards, the French, the Germans, and the English. Having thus traced the influences at work to produce diversity of national character among the inhabitants of Europe; it is requisite that I turn in the second place to those which produced a certain community of character.

II. The first and most powerful of these was the church. The people of Europe were, by name and country at least, Christians: and with all the natural tendency of men to split into schisms, there was a sufficient external pressure during the feudal period to make this common Christianity the source of a common feeling of citizenship. The north-eastern frontiers of the German empire were pressed upon by Sclavonic tribes, most of whom were heathens, and with whom an unintermitting series of petty hostilities were kept up. The Norsemen, so long as they retained the character of sea-kings or territorial conquerors, were heathens. From the south the Arabs had occupied Spain; and even after they were driven out of Sicily and the south of Italy, they carried on from Africa an unintermitting piratical warfare against all the Mediterranean coasts of Europe. The seat of the Popes—the centre and capital of the Christian church—was not at all times safe from their assaults. To the south-east, again, another body of Mussulmans, the Turks, in the course of this period succeeded in wresting Asia Minor from the Byzantine empire, and, about half a century before its close, crossed the Hellespont, reared the crescent on the walls of Constantinople, crossed the Danube, and pressed on to Vienna. They who exclaim about the absurdity of the Crusades should keep these facts in view. Those expeditions were not simply aggressive; they were to drive back a body of invaders from the south, where aggression seemed to have no limit: to erect a bulwark against the progress of the arms of Islam. The Crusades, the wars with the Moors in Spain, and the wars of the north-east frontiers of Germany, and against the northern marauders, kept alive a community of feeling and purpose among the six European people down to the close of the feudal period. It prevented the feeling of national worth which was springing up, from degenerating into a feeling of national exclusiveness. All these nations were taught to co-operate, and taught to appreciate each other. The organization of the Romish church did much to promote this common feeling; but this common feeling did much in turn to uphold the Romish church. No emotion or connection less intense could have prevented two or three independent churches arising out of the schisms and double elections of Popes in the thirteenth century.

Intimately connected with this influence of the one faith—and, indeed, proceeding in a great measure from the church—was the influence of literature, science, and art. It has been repeatedly noticed, that by the regulations of the church a school was to be maintained in each episcopal and prebendal church at the expense of the incumbents. Too often this duty was neglected; but it was sometimes discharged. The course of study was in all servility borrowed from the traditional Roman. First, the Trivium was taught grammar, rhetoric, and dialectics; next, to those who aspired to greater learning, the Quadrivium, music, arithmetic, geometry, and astronomy. As taught in the schools, these were mere cumberers of the memory; but as the relations of social life became more manifold, men's minds were awakened and set a-thinking, and more happily constituted minds found that the empty forms impressed upon their mind in youth were susceptible of being turned to use in investigating and classifying phenomena. The ritual of the church afforded a practical school for the advancement of music; commerce, navigation, architecture, fortification, afforded constant opportunities of extending the knowledge and practical application of the other sciences, and making these real studies, which, for a time, were empty form and prattle. As men's minds were strengthened by practical exertions, even grammar, rhetoric, and dialectics began to have a deeper meaning and influence. The scholastic form often lends an imposing appearance to empty gabble; but at times it is the repulsive exterior of deep and important thoughts. Under the impulse of minds trained in these healthier studies, the popular literature of Europe began to assume a more imposing form. The Dantes and Petrarchs of Italy, and the Chaucers of England arose; and at the time that these strides were making, the progressive overthrow of the Byzantine empire drew many learned Greeks to Europe, who brought with them the inestimable treasures of Athenian philosophy in the original language. The arts of design, too, had been prevented in Italy in consequence of the part taken by the Romish church in the controversy relating to the use of images in churches. The advancing literary taste inspired the artists. Cimaline, instructed in the stiff traditional Greek form of painting, endeavoured to imitate nature. His scholars followed out the path he indicated, carried to greater perfection the imitation of nature, and the grace of form. Raphael and his great contemporaries breathed the expression of life, passion, and feeling into these fair extensions—the idealised art. In some of the six nations the advances of science, art, and literature were more rapid than in others; but in all there was a community of thought and feeling amid discrepancy. Scholars and artists, and men of science throughout Europe, spoke, in the main, one language (though in various dialects), their thoughts were cast in the same mould—their sympathies were in unison. The groundwork of their knowledge, the logical forms in which their young minds were trained, were the same. The elements of every art they prosecuted were handed down to them from the same source.

Lastly, among these elements of one uniform European character there was a kindred likeness of form and spirit in the institutions and laws of all Europe. Local circumstances might evolve varieties, but the ground-work, the elements, were the same. The grand features of the feudal system were common to all: the municipal constitution, or its analogue, the rural county, shire, or *gau*, was common to all. The common law was vested in ecclesiastical judicatories wherever the authority of the Romish church was acknowledged. The municipal or civil law of every country in Europe was an amalgamation of the Roman law with that which had grown up amid the German forests. Local circumstances, temperament, the influence of events, had combined to produce varieties in the European character: religion, laws, literature, and art, all derived from sources common to all, combined to give it at bottom one family, pervading, identical character.

It is this discrepancy in uniformity which elicits all that is good and great in man. The servile and imbecile sameness which despotism, as in the Roman empire, stamps upon, superinduces stagnation in a mass. The repulsive influence of habits, formed amid such isolated communities as those upon the ruins of which Roman power was erected, keeps men apart—keeps them ignorant and unsocial. It creates the torpor and apathy of the lonely ascetic with the spiritual deadness of the worldling. But when men are brought into collision by the adventures and accidents of life, who, with one common substratum of principle and sentiment sufficient to enable them to understand each other, possess sufficiently marked and stubborn differences to excite wonder and contradiction, alternately disgust and reverence, they virtually excite and educate each other. This was the condition into which the progress of events, under Divine providence and superintendence, had brought European society at the period to which our attention is now directed; and the history of that period is a mere recapitulation of the moral phenomena evolved in consequence. Every power of man seems to be strengthened to preternatural power by sympathy. Dante, Petrarch, and Boccacia, in Italy, Chaucer in England, swung themselves up to a flight of poetry such as had not before been witnessed since the days of Homer. All over Italy and along the banks of the Rhine, painters and sculptors rival these masters of song, not only in expression of mere physical, but of moral and intellectual beauty. The profession of the mariner is directed to science, and the result is the discovery of a new world by Columbus. The power of Rome was undermined before a murmur was raised against it. The European nations and their kings were prepared for a simultaneous revolt against the monarchy of feudalism without being aware of their own aims. The mind of man had out-grown old forms, and was preparing itself for the effort that was to rend asunder the integuments that felt so galling. It was these deep and pervading causes that were at work: the explosion, the transformation must not be attributed to weaker agencies. The human mind was morbidly alive: the eternal self-renewing phœnix was preparing the spicy pile of poetry and sculpture, and painting and deep-versed philosophy and heroic enterprise, whereon to immolate its worn-out frame, in order that the re-incarnated spirit, strong of wing and bright of eye, might spring from amid the flames, the omen and augur of a new age,—an age which has at length burst upon us, with its freer political institutions, its improved social arrangements, its wondrous discoveries in physical science, and its still more wondrous applications of them; but an age which is itself destined to give place to another, as far in advance of this as this is in advance of the last.

USEFUL TABLES.

I.—ON THE STRENGTH OF THE TEETH OF WHEELS.

The following tables may prove useful to the mechanic, not only in assisting him to determine the strength necessary to be given to the teeth of any pinion, but for ascertaining the amount of engine or other power which any given wheel may safely carry.

Let H be the given number of horses' power transmitted by the wheel; p, the pitch of the teeth; n, the number of the revolutions of the wheel per minute; and t, the number of the teeth of the wheel. Then

I. For Cast-iron teeth,..... $H = \dfrac{n\,t\,p^3}{12^3} = \dfrac{n\,t\,p^3}{1728}$.

II. For Brass teeth,...... $H = \dfrac{n\,t\,p^3}{13^3} = \dfrac{n\,t\,p^3}{2197}$.

III. For Hard-wood teeth, $H = \dfrac{n\,t\,p^3}{14^3} = \dfrac{n\,t\,p^3}{2744}$.

The unit of H is here taken, for safety, at 42,000 lbs., raised through 1 foot per minute; and consequently its value referred to water power, for which 33,000 lbs. raised through the same unit of space per m. is a horse power, will be $\frac{14}{11}$ times the latter. For the first and third of these formulæ, the following tables of coefficients have been calculated for convenience in practice.

Table I.—For Cast Iron Teeth.

$$H = \frac{n\,t\,p^3}{12^3} = \frac{p^3}{12^3} \times n\,t.$$

Values of p in inches.	Values of $\frac{p^3}{12^3}$	Logs of $\frac{p^3}{12^3}$
$\frac{1}{2}$	·000072	$\bar{5}$·859369
$\frac{5}{8}$	·000141	$\bar{4}$·150096
$\frac{3}{4}$	·000244	$\bar{4}$·387639
$\frac{7}{8}$	·000388	$\bar{4}$·588480
1	·000579	$\bar{4}$·762456
$1\frac{1}{8}$	·000824	$\bar{4}$·915915
$1\frac{1}{4}$	·001130	$\bar{3}$·053186
$1\frac{3}{8}$	·001504	$\bar{3}$·177365
$1\frac{1}{2}$	·001953	$\bar{3}$·290729
$1\frac{5}{8}$	·002483	$\bar{3}$·395015
$1\frac{3}{4}$	·003102	$\bar{3}$·491570
$1\frac{7}{8}$	·003815	$\bar{3}$·581459
2	·004630	$\bar{3}$·665546
$2\frac{1}{8}$	·005553	$\bar{3}$·744533
$2\frac{1}{4}$	·006592	$\bar{3}$·819005
$2\frac{3}{8}$	·007753	$\bar{3}$·889448
$2\frac{1}{2}$	·009042	$\bar{3}$·956276
$2\frac{5}{8}$	·010468	$\bar{2}$·019843
$2\frac{3}{4}$	·012035	$\bar{2}$·080455
$2\frac{7}{8}$	·013752	$\bar{2}$·138370
3	·015625	$\bar{2}$·193820
$3\frac{1}{8}$	·017661	$\bar{2}$·247006
$3\frac{1}{4}$	·019866	$\bar{2}$·298105
$3\frac{3}{8}$	·022247	$\bar{2}$·347278
$3\frac{1}{2}$	·024812	$\bar{2}$·394660
$3\frac{5}{8}$	·027566	$\bar{2}$·4 0380
$3\frac{3}{4}$	·030518	$\bar{2}$·484549
$3\frac{7}{8}$	·033672	$\bar{2}$·527272
4	·037037	$\bar{2}$·568636
$4\frac{1}{4}$	·044425	$\bar{2}$·647623
$4\frac{1}{2}$	·052735	$\bar{2}$·722095

Table II.—For Hard wood Teeth.

$$H = \frac{n\,t\,p^3}{14^3} = \frac{p^3}{14^3} \times n\,t.$$

Values of p in inches.	Values of $\frac{p^3}{13^3}$	Logs of $\frac{p^3}{14^3}$
1	·000364	$\bar{4}$·561616
$1\frac{1}{8}$	·000519	$\bar{4}$·715075
$1\frac{1}{4}$	·000712	$\bar{4}$·852346
$1\frac{3}{8}$	·000947	$\bar{4}$·976525
$1\frac{1}{2}$	·001230	$\bar{3}$·089889
$1\frac{5}{8}$	·001564	$\bar{3}$·194175
$1\frac{3}{4}$	·001953	$\bar{3}$·290730
$1\frac{7}{8}$	·002402	$\bar{3}$·380619
2	·002915	$\bar{3}$·464706
$2\frac{1}{8}$	·003497	$\bar{3}$·543693
$2\frac{1}{4}$	·004151	$\bar{3}$·618165
$2\frac{3}{8}$	·004882	$\bar{3}$·688608
$2\frac{1}{2}$	·005694	$\bar{3}$·755436
$2\frac{5}{8}$	·006592	$\bar{3}$·819003
$2\frac{3}{4}$	·007579	$\bar{3}$·879615
$2\frac{7}{8}$	·008660	$\bar{3}$·937530
3	·009840	$\bar{3}$·992980
$3\frac{1}{8}$	·011122	$\bar{2}$·046166
$3\frac{1}{4}$	·012510	$\bar{2}$·097265
$3\frac{3}{8}$	·014010	$\bar{2}$·146438
$3\frac{1}{2}$	·015625	$\bar{2}$·193820
$3\frac{5}{8}$	·017360	$\bar{2}$·239540
$3\frac{3}{4}$	·019218	$\bar{2}$·283709
$3\frac{7}{8}$	·021205	$\bar{2}$·326432
4	·023324	$\bar{2}$·367796

We have not expanded the rule for brass teeth, as it is of little practical value.

To illustrate the use of these tables, let us suppose a cast-iron wheel of 60 teeth and $2\frac{3}{4}$ inches pitch, making 85 revolutions per minute; what amount of steam-engine power is it capable of transmitting? In this example,

$$\left.\begin{aligned} p &= 2\tfrac{3}{4} \\ n &= 85 \\ t &= 60 \end{aligned}\right\} \text{ then } H = \frac{p^3}{12^3} \times n\,t = \cdot 012035 \times 85 \times 60$$
$$= 61\cdot 38 \text{ nearly.}$$

To accommodate those who may prefer to make the calculations by logarithms, we have added a column containing the logarithms of the coefficients, which, for greater accuracy, may be employed instead of the coefficients themselves. Thus, in the preceding example, we have

Log ·012035 = $\bar{2}$·080455
Log 85 = 1·929419
Log 60 = 1·778151

Log 61·38 = 1·788025

that is 61·38 is the value of H, as before.

By the inverse of these rules we find the pitch answering to given values of H; n and t being also given. Thus,

I. For cast-iron teeth, $p = 12 \sqrt[3]{\dfrac{H}{nt}} = \sqrt[3]{\left(\dfrac{1728\ H}{n\,t}\right)}$

II. For brass teeth, $p = 13 \sqrt[3]{\dfrac{H}{nt}} = \sqrt[3]{\left(\dfrac{2197\ H}{n\,t}\right)}$

III. For hard-wood teeth, $p = 14 \sqrt[3]{\dfrac{H}{nt}} = \sqrt[3]{\left(\dfrac{2744\ H}{n\,t}\right)}$

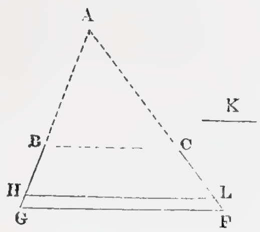
These rules are founded on the assumption that the breadth of the tooth shall not be less than double its length, and that strength cannot be gained by further increase of breadth.*

* See an article on this subject in Vol. I. p. 95.

MISCELLANEOUS PROBLEMS IN MIXED MATHEMATICS.

PROB I.—*To divide an irregular four-sided field,* B C F G, *into parallel acres.*

Produce the lines G B, and F C, till they meet in A. Construct the triangle A H L, similar, and similarly situated with A G F, and less than it by K^2 (Eu. VI. 25); then is the trapezoid H F one of the figures required. In like manner straight lines can be drawn between H L and B C, and parallel to G F and H L, and containing spaces also equal to K^2.



Otherwise.—Having produced B G and F C to meet in A, find H so that

$$GAF : GAF - K^2 = AG^2 : AH^2$$

Through H thus found, draw H L parallel to G F; then H F as before $= K^2$.

Scholium.—By the foregoing, a method is suggested for the division of any piece of land into parallel stripes, and each portion containing any quantity whatever that may be desired.

The computation of the example given above would, perhaps, be more laborious than advantageous; we may indicate, however, that it may be shortened by the ordinary rules of trigonometry and mensuration. Thus having found the area of the figure $GAF = 2352667$ square links; and the line $AG = 3377$ links, take the second solution and say

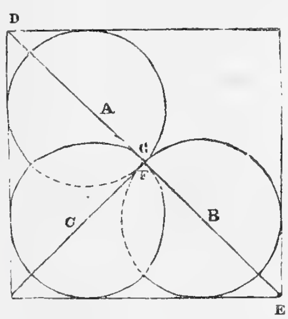
$$GAF : GAF - K^2 = AG^2 : AH^2$$

Whence we get $AH = 3306$ links nearly;

Then $HG = AG - AH = 3377 - 3306 = 71$ links.

The further subdivision must be carried on in the same way making use of the above proportion in each instance.

PROB. II.—*Required the smallest cubical box which will contain three spheres of six inches diameter each.*



Let D E be the bottom of a square box, such that two of the spheres, A and B, touch one another at G, and also the sides of the box; and let D E be a line passing through the centres of the spheres.

Let the radius of the spheres $= a$, then $\sqrt{2\,a^2} = AD = 4{\cdot}243$ inches.

$\sqrt{2\,(AD + a)^2} =$ a side of the box $= 10{\cdot}243$ inches.

Now, if the centre C, of the ball C, be joined with the point G, where the other two impinge, and if a perpendicular to the bottom of the box pass upwards through G, it will plainly touch the sphere C at F.

then, $\sqrt{CG^2 - a^2} = GF$,

And $GF + 2\,a =$ the height of the box $= 10{\cdot}243$ inches, which shows that the box is cubical, and that it is the smallest that will contain them.

PROB. III.—*If a governor make four revolutions in a second, when the ring is twenty-five inches from the top; what will be the distance of the ring if the speed be increased to ten revolutions per second, the length of the pendulum rod, and radius of guard-ring being given?*

Let $l =$ length of pendulum-rod of the governor; $n =$ its revolutions per minute, to be altered to N revolutions in the same time; $d =$ distance of guard-ring from the vertex when making n revolutions per minute, and we will suppose that it is curved to the arc of a circle of radius d, which is generally the case before its position on the stem of the governor has been altered. Also, let $x =$ its distance from the vertex, to correspond with N revolutions per minute, and $\varphi = 35016{\cdot}624$.

Then at n revolutions, the height of the cone of revolution is $\frac{\varphi}{n^2}$ and its radius is $\left(l^2 - \frac{\varphi^2}{n^4}\right)^{\frac{1}{2}}$. And $l : \left(l^2 - \frac{\varphi^2}{n^4}\right)^{\frac{1}{2}} :: d :$ $\frac{d}{l}\left(l^2 - \frac{\varphi^2}{n^4}\right)^{\frac{1}{2}} =$ horizontal extent of guard-ring. Also,

$l : \frac{\varphi}{n^2} :: d : \frac{d\,\varphi}{l\,n^2} =$ the cosine of its curvature, and therefore

$d - \frac{d\,\varphi}{l\,n^2} = d\left(1 - \frac{\varphi}{l\,n^2}\right) =$ the versed sine of the same.

Whence, sine $\frac{\varphi}{N^2}$ and $\left(l^2 - \frac{\varphi^2}{N^4}\right)^{\frac{1}{2}}$ are the height and radius for N revolutions.

$$\therefore x - d\left(1 - \frac{\varphi}{l\,n^2}\right) : \frac{d}{l}\left(l^2 - \frac{\varphi^2}{n^4}\right)^{\frac{1}{2}} \;.\,:\; \frac{\varphi}{N^2} : \left(l^2 - \frac{\varphi^2}{N^4}\right)^{\frac{1}{2}},$$

$$\text{and } x = d\left\{\frac{1}{l}\cdot\frac{\varphi}{N^2}\left(\frac{l^2 - \frac{\varphi^2}{n^4}}{l^2 - \frac{\varphi^2}{N^4}}\right)^{\frac{1}{2}} + 1 - \frac{1}{l}\cdot\frac{\varphi}{n^2}\right\}$$

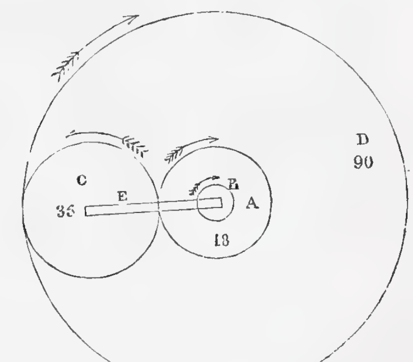
For an example, take, instead of the numbers in the problem, $n = 40$ revolutions per minute, to be altered to $N = 50$ revolutions; $l = 28$ inches, and $d = 24$ inches. Then $\frac{\varphi}{n^2} = 21{\cdot}8854$

$\frac{\varphi}{N^2} = 14{\cdot}0067$; and,

$$x = 24\left\{\frac{14{\cdot}0067}{28}\left(\frac{28^2 - 21{\cdot}8854^2}{28^2 - 14{\cdot}0067^2}\right)^{\frac{1}{2}} + 1 - \frac{21{\cdot}8854}{28}\right\} = 13{\cdot}89$$

inches from the vertex.

PROB. IV.—A *is a spur wheel of* 18 *teeth, which runs loose on the shaft,* B; *this wheel gears into another,* C, *of* 35 *teeth, which gears*



into an internal toothed wheel, D, *of* 90 *teeth. The wheel,* C, *is connected by a lever,* E, *to the shaft,* B, *and revolves with it between the inside of the internal wheel,* D, *and the outside of the small wheel,* A *(revolving at the same time in its own plane, on a pin at the end of the lever,* E*). Now, supposing the shaft,* B, *revolves* 150 *times, and the wheel,* A, 135·625 *times per minute, what is the speed of the internal wheel,* D*? And*

1*st. Can the pinion of* 18 *teeth be driven at such a speed as to cause the internal toothed wheel to* STOP; *if so, what is that speed?*

2*d. Can the internal wheel be made to revolve the* CONTRARY *way, the pinion and shaft revolving* AS USUAL; *if so, at what speed must the pinion revolve for the internal wheel to make* 100 *revolutions per minute?*

3*d. Supposing the* PINION *were to revolve the contrary way, would it increase or diminish the speed of the internal wheel, and in what ratio?*

Before proceeding to resolve the questions involved in the problem, let us consider the different modes of the working apparatus; and first,

Suppose the shaft B and the pinion A, to have both the same motion—say 150 revolutions per minute—then it is evident that the same teeth of the intermediate wheel C will continue to gear into A and D; and, consequently, D will move with the same velocity as A and B, viz., 150 revolutions per minute.

But, suppose that the pinion A, moves faster or slower than the shaft B, how will this affect the internal wheel D? If it moves *faster*, then it will communicate a left-hand motion to the wheel C, (by a left-hand motion, we mean, that, the reverse of the hands of a watch,) and, consequently, C will drive the internal wheel D in the opposite direction of that in which it is driven by the shaft B, and thus its motion in that direction will be retarded.

But if A moves *slower* than B, then A will give C a right-hand motion; this will give D a forward movement—in the direction in which B is driving it—consequently, D will be accelerated.

In what ratio will D be retarded in the one case, and accelerated in the other? Evidently in the proportion of the number of teeth in A, to the number of teeth in D; that is, if the pinion A moves 149 revolutions per minute, (one less than the shaft B), it will accelerate D the number of teeth it contains (viz., 18,) per minute. D will thus move 150 revolutions, *plus* eighteen teeth, or $150\frac{1}{5}$ revolutions per minute. From this we discover, that the number of revolutions which the pinion A makes less than the shaft B, divided by the number of times A is found in D (that is, $\frac{90}{18} = 5$·) added to the motion of the shaft B, is equal to the speed of D; or, in a plain formula, $\frac{B - A}{5} + B = D$.

From this formula the whole of the questions in the problem can be easily worked; premising that, when the pinion, A, is given revolving in a *contrary* direction from the shaft, B, its number of revolutions must be *added* to those of B, for the difference between them. And, again, when the answer is a *minus* or *negative* quantity, the wheel D is revolving in a *contrary* direction from shaft B. It will also be observed, that the number of teeth in the intermediate wheel C is not taken into account—this being unnecessary, as C is merely a *conductor* of motion. Now for the questions:—First, " Given the shaft B, revolving 150 times, and the pinion A 135·625 times per minute, what is the speed of the internal wheel D?" $\frac{B - A}{5} + B = D$, $\therefore \frac{150 - 135{\cdot}625}{5} + 150 = D$, or, $\frac{14{\cdot}375}{5} + 150$, or $152{\cdot}875 =$ speed of D.

Second question, " Can the pinion of 18 teeth be driven at such a speed as to cause the internal toothed wheel to *stop;* if so, what is that speed?"

From the formula $\frac{B - A}{5} + B = D$, we obtain $6B - 5D = A$; in this case, B is 150, and D is 0, $-\therefore 900 =$ speed of A.

Third question, " Can the internal wheel be made to revolve the *contrary* way, the pinion and shaft revolving as usual; if so, at what speed must the pinion revolve, for the internal wheel to make 100 revolutions per minute?"

Take the formula used above, $6B - 5D = A$, here B is 150, and $D - 100$, $\therefore 900 + 500$, or $1400 = A$.

Fourth question, " Supposing the pinion were to revolve the *contrary* way would it increase or diminish the speed of the internal wheel, and in what ratio?"

It would increase it in the ratio of 90 to 18, or 5 to 1. Were A stationary, D would move $\frac{150}{5} + 150$ or 180 times per minute; and for every five turns that A moves left-hand, D is increased *one* in velocity.

Another form of the Solution.

Let $R\ R'\ R''$ be the radii of the sun, planet, and external wheels, and let $\alpha\ \beta\ \gamma$ be their angular motions. Also let δ be the angular motion of the shaft, or of the radius carrying round the planet wheel.

If we suppose the sun wheel to be at rest, and that by a given motion δ of the shaft, the planet wheel is brought to a new position in its orbit, an arc of its circumference will have rolled over an equal arc $R\,\delta$, of the circumference of the sun wheel, so that the point of its circumference, which before motion was in contact with the sun wheel, will be left behind the new point of contact attained by the change of position. And the distance between these two points, measured on the circumference of the planet wheel, will be equal to the a c $R\,\delta$ of the sun wheel

If now the sun wheel is moved round an arc α, the first of these points of contact will be moved over an arc of equal length, approaching to, or receding from the second, according as the motions of the sun wheel and shaft have been in the same, or in contrary directions. So that, the ultimate distance between them, or the angular motion β of the planet wheel, will be equal to the sum or difference of the arcs $R\,\delta$, $R\,\alpha$ of the sun wheel.

In a similar way, the motion of the external wheel is compounded of two other motions. One of them the angular motion of the shaft at the extremity of the radius R'' and therefore equal to $R''\,\delta$; the other derived from, and equal to, that of the planet wheel about its centre.

Hence, reckoning motion in the direction of the motion of the shaft positive, and that in the opposite direction negative these two equations,

$$R\,(\delta - \alpha) = R'\,\beta \text{ and } R''\,\delta + R'\,\beta = R''\,\gamma$$

As none of the queries relate to the motion of the planet wheel, we may substitute the value of $R'\,\beta$ given by the first of these, for $R'\,\beta$ in the second; which gives after dividing both sides by R'' the general equation

$$\delta + \frac{R}{R''}(\delta - \alpha) = \gamma$$

To apply this equation to the given queries, it must be observed that the angular motions α, δ, are also the number of revolutions in a given time; and that $R\ R'$, may represent the numbers of the teeth of the respective wheels, as these numbers are proportional to the radii. We have therefore $R = 18$, $R'' = 90$, $\delta = 150$, and $\alpha = 135{\cdot}625$. Substituting these in the above equation, we have

$\gamma = 150 + \frac{18}{90} \times (150 - 135{\cdot}625) = 152{\cdot}875$ revolutions per minute.

For the external wheel to remain at rest, we must have $\gamma = 0$, which cannot be the case unless $\frac{R}{R''}(\delta - \alpha)$ be negative; α must therefore be greater than δ. and the equation becomes

$$\delta - \frac{R}{R''}(\alpha - \delta) = 0 \therefore \alpha = \frac{R'' + R}{R}.\delta$$

that is $\alpha = \frac{90 + 18}{18} \times 150 = 900$ revolutions per minute.

If α has a value assigned to it greater than $\frac{R'' + R}{R}.\delta$, the external wheel will revolve the contrary way; for then $\frac{R}{R''}(\alpha - \delta)$ will be greater than δ, which will make γ negative.

$$\text{Hence } \alpha = \frac{(R'' + R)\,\delta - \gamma\,R''}{R}$$

So that if $\gamma = -100$ we have $\alpha = 1400$ revolutions per minute.

If the pinion revolves the contrary way α will be negative, and the factor $\delta - \alpha$ of the general equation becomes $\delta - (-\alpha) = \delta + \alpha$, and the equation becomes

$$\delta + \frac{R}{R''}(\delta + \alpha) = \gamma$$

Comparing this with the first, it will appear that the values of γ for equal motions, but in opposite directions of the sun wheel, are in the ratio of $\delta + \frac{R}{R''}(\delta + \alpha)$ to $\delta + \frac{R}{R''}(\delta - \alpha)$,

$\therefore$ Taking $\alpha = \pm 135{\cdot}625$, we have $\gamma = +152{\cdot}875$, and $= +207{\cdot}125$, the first corresponding to the positive, and the second to the negative direction of the sun wheel's motion; and for both these values of α, the internal wheel revolves in the same direction.

WERTHEIMER'S CALCULATING MACHINE.

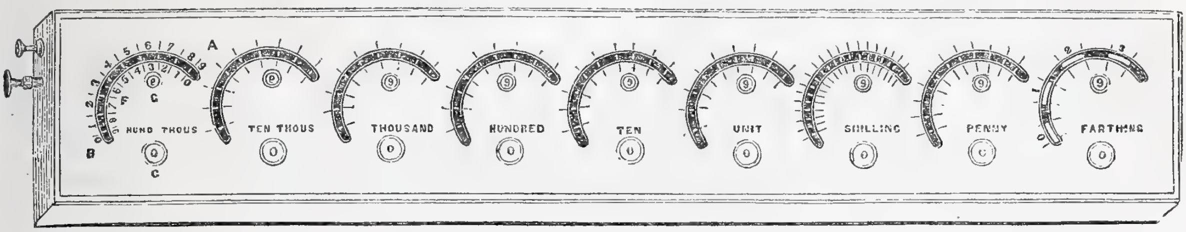
VARIOUS attempts have been made, from time to time, to shorten or supersede the labour of arithmetical calculations by the aid of mechanical contrivances. The celebrated Pascal invented a machine that could perform the four fundamental operations, and Leibnitz constructed one of still more extensive powers; but neither of these engines proved of any practicability, and they have become mere matters of history. The most famous attempt of this sort is the great arithmetical machine contrived by Mr. Babbage, towards the construction of which he obtained a grant from Parliament more than thirty years ago; but the machine was never finished, although it is said that upwards of £15,000 were expended upon the work

Mr. Babbage's machinery was to consist of two distinct parts; the one capable of computing and exhibiting the successive terms of any series whose differences, of whatever order, become constant, and the other so arranged as to punch upon copper the figures of the numbers so produced, and from the impression thus made stereotype plates were to be cast for printing the tables calculated by the machine. If their object could have been attained, the benefits that would have been conferred upon society generally, but especially upon those engaged in scientific pursuits, could scarcely be overstated, for we might have had tables for all conceivable uses, from the reckoning of prices and interest up to the most laborious and intricate calculations of astronomy: all computed—and what is practically of equal importance—all printed with unfailing accuracy. Mr. Babbage actually effected his object to a certain extent. His engine developed, for example, the formula $x^2 + x + 41$, in which the second differences are constant, and gave the following table:—

41	131	383	797	1373
43	151	421	853	1447
47	173	461	911	1533
53	197	503	971	1601
61	223	547	1033	1681
71	251	593	1097	1763
83	281	641	1163	1847
97	313	691	1231	1933
113	347	743	1301	2021

Several "automaton calculators" were shown at the Great Exhibition in 1851. One of these, adapted for performing the operations of the four arithmetical rules—addition, subtraction, multiplication, and division—and applicable for addition and subtraction of English money, from one farthing up to one million pounds sterling, was contrived and patented by Dr. Roth and M. Wertheimer. It is very simple, ingenious, and efficient; and as a description of it may be interesting to our readers, we shall attempt to explain its mode of working and the principle of its action. We are apt to consider, that along with what we would call the mere drudgery of calculation, there is also mixed up a considerable amount of intellectual effort. The inspection of this little instrument, while it surprises, should also humble us when it demonstrates how purely mechanical the processes are which constitute the principal part of the mental exertion made by a large portion of the community, and shows us, while many regard expertness in computation no mean proof of intellectual superiority, how much better the feat on which they plume themselves can be performed by a train of wheel-work.

Fig. 1.



The "automaton calculator" is capable of adaptation to any scale of units. The instrument represented in the subjoined sketch is accommodated to the subdivisions of British money. It consists of a box about 15 inches long and 2 inches broad, with a metal plate on the top. The plate is divided into nine indices, with semicircular notches; the first six from left to right serve for setting down the numbers of the pounds, from hundred-thousands to units; and the three last are appropriated to shillings, pence, and farthings.

Round the indices are engraved figures, as shown from A to B, and the semicircular notches contain teeth to correspond with the figures. Under the indices is a succession of holes, C, which present in a horizontal line the number set down. This line or table must be set to 0 before any operation is commenced.

To inscribe any given number, a pointer or style—which is shown in its place at the end, where it lies when not in use—is inserted vertically in the notch corresponding with the figure required to be set down; the notch is then brought from right to left to the end of the semicircle. This causes a revolution of the wheel through an arc corresponding to as many teeth as there are units in the digit inscribed, and a number passes the hole, C, for every tooth of the wheel. Suppose it is desired to write a sum of £4,703. 12s. $8\frac{3}{4}$d. The pointer is inserted in the notch corresponding with the figure 4 under the thousands, and brought down to the left end of the semicircular slit. This turns the wheel through 4 teeth, and the number 4 appears in the hole below. The same is done with figure 7 in the hundreds; the *tens* are passed by, as 0 is the next figure required. The pointer is then inserted in succession into 3 in the units index, 12 in the shillings, 8 in the pence, and 3 in the farthings, and brought down to the extreme left of each of the slits.

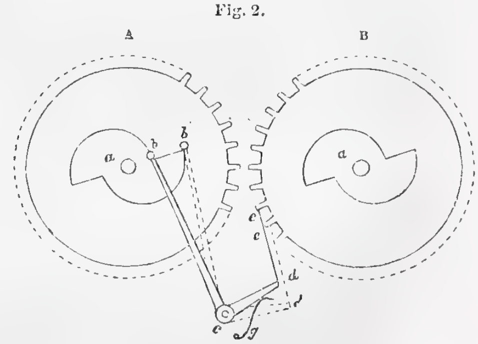
When this is done, the table exhibits the sum £4,703. 12s. $8\frac{3}{4}$d. Any other sum or succession of sums may be inscribed in the same manner, and the table will continually exhibit their aggregate amount until it reach a million, which is the limit of the instrument represented above.

As a number passes the hole, C, for every tooth that the wheel is moved, this result will be readily comprehended when it is stated that the wheels are so connected, that during the passage of every index from its highest figure to 0, the wheel to which it is attached moves the wheel immediately on the left of it, containing units of the order next above it, through one notch, that is to say, it *carries* 1 to the denomination next higher.

The arrangement by which this is effected will be understood from the annexed diagram, which represents two of the wheels as they would be seen from behind.

Every wheel has as many teeth in its semicircumference as there are units of its order in one unit of the order next higher. A semi-revolution of the wheel, A, ought, therefore, to push the wheel, B, forward by one tooth. Every wheel is furnished with a double eccentric, a. The motion is from left to right, and during a semi-revolution the ascending eccentric on A carries the end, b, of the crutch, $b\ c\ d$, from b to b'. At this point, the continued motion of the wheel permits the extremity, b, of the crutch to be pushed over the abrupt face of the eccentric by the pressure of a spring, g. The crutch thus alternates between the two positions, $b'\ c\ d'$ and $b\ c\ d$. The limb, $c\ d$, carries a spring or pallet, $d\ e$, which presses against the teeth of the wheel, B, and the passage of the limb, $b\ c$, from the position, $b'\ c$, to the position, $b\ c$, depresses the limb, $c\ d$, sufficiently, to allow the pallet to introduce itself below another tooth, which it holds, and by means of which it advances the wheel, B, by one unit at the moment the other limb, $b\ c$, falls from it upper

Fig. 2.



to its lower position. This fall corresponds with the passage of the dial from 9 to 0 (or 19 to 0, as the case may be), and thus, when the numbering on the dial is exhausted, and the indications are about to be recommenced, the wheel to which it is attached moves the adjoining wheel forward by one tooth, in this way *carrying* 1 to the next higher denomination.

The great excellence of this arrangement is the almost entire absence of friction, the communications of the wheels being successive, not simultaneous. Thus, although, when the indication of the dials is £9,999. 19s. 11¾d., the addition of 1 farthing causes a motion sensibly instantaneous in eight dials, so as to produce an indication of £10,000; yet every wheel is moved consecutively in regular succession from right to left.

For performing subtraction there is another set of holes, G, in which red figures appear; they are arranged in the reverse order of the black figures that are shown in C, but as the instrument can only in this way operate the continual reduction of one original amount, it is of no practical utility, and, the process being merely the reverse of continual addition, its principle will be readily enough comprehended from what is stated above.

For the sake of simplicity, we have described the machine in its original form, as calculated only for performing addition and subtraction. The machine, as adapted for multiplication, consists, to all outward appearance, of nine adding machines in one frame. The lowest one is precisely an adding machine such as we have described, but in all the others the connection exists between two wheels adjacent vertically, and not laterally; that is to say, the wheels in the horizontal rows are quite unconnected with each other; but in the vertical columns they are connected in such a manner that one revolution of a wheel in the second row from the bottom will cause two revolutions of the corresponding wheel in the bottom row. A revolution of a wheel in the third row, will occasion three revolutions of the corresponding wheel in the bottom row, and so on upwards to the ninth row—every wheel producing by one revolution the number of revolutions in the lowest wheel, that is indicated by the number of the row in which it stands. The wheels of the lowest row have, therefore, a communication both vertically and horizontally—the wheels of all the others have a vertical connection only. It is easy to see how an instrument constructed in this manner could perform multiplication. Let the annexed figure represent the instrument, and suppose, for example, we have to multiply 476 by 367.

If we inscribe 476 in the row No. 7, putting the units in the units column, it is clear that 7 times that amount will appear in the row No. 1, because one tooth in No. 7 is equivalent to 7 teeth in No. 1. Again, if we inscribe the multiplicand 476 in the row No. 6, beginning with the units in the tens place—the extent to which the dials in No. 1 will be affected will be 476 × 6 × 10. Lastly, let 476 be inserted in row No. 3, beginning with the units in the hundreds place, and the result, as exhibited in the lowest row, will necessarily be 476 × 367. For we have accumulated in its line of holes

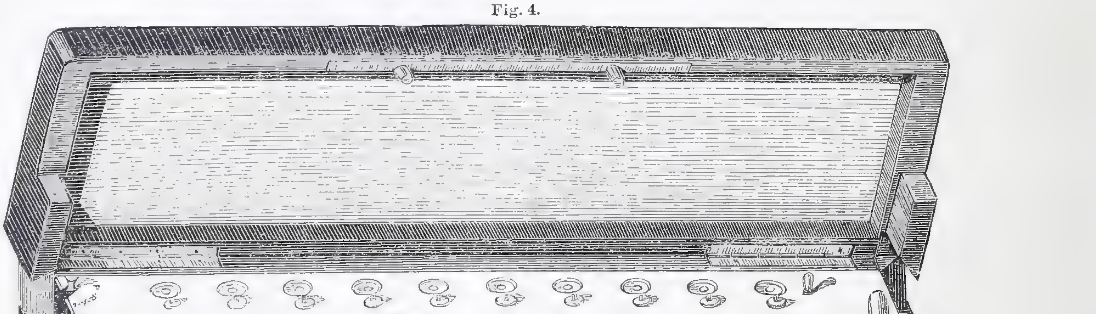
Fig. 3.

									(9)
									(8)
						4	7	6	(7)
					4	7	6		(6)
									(5)
									(4)
				4	7	6			(3)
									(2)
			1	7	4	6	9	2	(1)

$$\left.\begin{array}{l} 476 \times 7 \\ + 476 \times 6 \times 10 \\ + 476 \times 3 \times 100 \end{array}\right\} = 476 \times 367 = 174692$$

In the same manner it would exhibit the sum of any number of products within the limits of its range, by simply writing the figures of one of the factors in the rows corresponding to the figures of the other. It will thus offer a ready means of calculating the average date of an account current or an account of sales; a laborious operation, of frequent occurrence in actual practice, and necessary for the equitable adjustment of interest in transactions extending over any considerable period.

Fig. 4.



The other calculating machines which were exhibited in the Crystal Palace included one by a Russian inventor, one by a Swiss, and four or five in the French department. Annexed is a sketch of one of the French machines, M. Thomas's Arithmometer. This apparatus is likewise intended for performing operations in the four common rules of arithmetic. The arrangement is similar in principle to that of the celebrated Napier's rods and lines. The Rabdologia, or book containing the description and use of these rods, was published in 1617, three years after the "Canon Mirificus Logarithmorum," or *Wonderful Rule of Logarithms*, a work which changed the face of Europe as to arithmetical calculations, and the value of which can never be superseded by any new invention. Napier's rods were made of bone,

ivory. or wood, and had their faces divided into nine little squares, the latter being diagonally divided into two triangles. In these were written the numbers of the multiplication table, the units being in the triangle on the right, and the tens in that on the left. The common operations of arithmetic were performed by arranging these rods with the hand, according to certain rules; and it is obvious that, by turning a handle, as in the machine of which a sketch is annexed, the same manipulation may be effected. But we have said enough to explain to the reader the principle and practicability of these machines, which have hitherto failed of acquiring a practical value, and are only regarded as scientific curiosities, the instruments being too expensive, even in their simplest form, for general use.

DOUBLE AND VERTICAL DRILLING MACHINES.

By M. Frey, Engineer, Belleville.

The double and vertical drilling machines constructed at the workshops of M. Frey, are designed for the refitting establishments connected with the French Railway du Nord, and that of Lyons.

They exhibit in their general aspect a round central column, which serves as a point of support to all the moveable pieces of which they consist.

To the body of the column are fitted four brackets—two above and two below; the former serving as a sliding support to the system of tool-holders; the other two fulfilling the same office for the horizontal plates or tables supporting the articles on which the work is performed. At the top of the column, and placed together on the same shaft, are two series of pulleys, communicating motion to each of the systems of which the machine is composed.

The two horizontal supports, which receive the pieces to be drilled, may be moved in a vertical direction in the slots to which they are firmly pinned, when it is desired to fix them in the execution of the work. Their height is regulated by means of a screw which is turned by a handle, and which has its point of support on the lower plate-rest.

These machines may be constructed with the two systems of tool-holders either similar or different, as may be desired; in the latter case, they have much analogy with those of the simplest form, and most generally in use. The other system has this peculiarity about it, that the height of the tool is regulated at pleasure by means of a circular rack gearing. A brake is attached to it, which, when firmly locked in the pinions of the pulleys, renders the latter immoveable. The circular rack or screw then pushes forward the drill which is mounted upon it, by a distance equal to the pitch of the screw for each turn it receives. If, on the contrary, the brake is only partially inserted in the gearing, the pulleys admit of being moved by a moderate effort. It is obvious that the screw which governs the drill, and which forces it to penetrate the metal by a distance equal to its pitch for each turn, must finally come into contact with the metal, which opposes a certain resistance to its progress; now, if this resistance is greater than that of the brake, it forces the screw to turn the pinions on which it rests, but as the point on which it is supported recoils, the speed with which the drill penetrates the metal diminishes.

Hence it happens, that to regulate the speed with which the drill advances, the brake must be fixed with a certain firmness in the gearing. And therefore, that the drill may advance with the same speed as the screw by which it is driven forward, the point on which the latter is supported must be fixed, and this is effected by firmly securing the brake. If it be desired, on the contrary, to cause the drill to advance at a slower speed than the screw, the supporting point of the screw must be rendered moveable; and this is accomplished by relaxing the hold of the brake to a corresponding degree.

This action will be better understood by referring to the annexed engravings, (figs. 1—5,) two of which exhibit the entire machine, and the others certain details.

Fig. 1 is a front view, with two different systems of tool-holders; fig. 2 is a side view of the same machine.

Fixed Pieces.—The column, *a*, which serves as the frame or trunk of the machine, is of cast-iron, formed in one piece with the plate, *b*, which is bolted to the slab, *c*. Over this part will be observed the two projecting pieces, *a′*, which serve, as we have stated, for slides to the brackets, *d*. Two other dovetailed projecting ribs serve the same purpose for the tool-supporters, *e*.

At the top of the column, *a*, rise three branches; two of which are bent in a circular form, to serve as supports to the driving shaft.

This shaft, *f*, which appears to be in one piece, is really divided in the middle of its length into two parts, that each of the parts may turn in different directions, or with different velocities in the same. The pulleys which are mounted on each of these shafts, are five in number. The larger ones, *h h′*, are the driving pulleys, and one of each of the pairs, *h′*, is loose on the shaft, for the purpose of arresting the movement when necessary. The three other pulleys, *g*, are in one piece, and form a cone, by which the rotatory movement is transmitted to the pulleys, *j*, of the tool-bearers.

Moveable Parts—*The tool-bearers.*—In the double machine, the shaft, *i*, called the tool-holder, is of wrought-iron, turned exactly cylindrical and equal in its whole length, to enable it to slide in the supports by which it is held. Its lower part only is enlarged, to receive into a hole, drilled for the purpose, steel bits, or drills. Along a portion of it, equal to its greatest range, are two longitudinal slots, exactly opposite to each other, in which the driving pinions, *k*, are keyed; this arrangement permits the tool-holder to rise and fall at pleasure, without carrying along with it the pinions, *k*.

Pressure of the Tools.—In this machine, the inventor has deemed it preferable to cause the pressure on the tool to be exerted by the person in charge of it, instead of leaving this operation to the machine itself, as is generally the case.

For this purpose, in one of the systems—that on the left, for example—the tool-bearing shaft receives at its upper part a screw, *l*, to which it is connected by a gearing represented in detail in fig. 3. On this screw is riveted a wheel, *m*, which receives its movement from a pinion, *n*; the latter is fixed at the extremity of a vertical shaft, *o*, firmly connected with the frame of the machine, and which, at its base, carries a winch, *p*. If the handle is turned, the pinion, *n*, will drive the wheel, *m*, as also the screw, *l*, on which it is mounted; and as this screw passes through a nut, *s*, it will raise or depress the tool-bearing shaft, according as the handle is turned in the one direction or the other.

A mechanism totally different is applied to the second tool-holder; indeed, it will be seen from fig. 2, that the tool-bearing shaft, *i*, on the right, is balanced by a counterweight, *q*, suspended to a chain passing over the pulley, *r*. The middle of the tool-holder is formed into a fine-threaded screw; on each side of which, two grooved pulleys or rollers, *t*, work into the threads of the screw, their journals resting on supports which have been cast in the same piece with those of the tool-holders. These journals are unequally prolonged on one side, the longest being fitted at its end with a winch-handle, *u*, fig. 2. It has been already shown, that by this arrangement the height may be adjusted to different points, by raising with the handle the shaft, *i*, on which it is fitted, and which is balanced by the counterweight, *q*. The rotation of the grooved pulleys, *t*, is then caused by their gearing with the screw of each of the tool-holders.

Another method of producing the same effect consists in turning one of the rollers, *t*, by its winch-handle, and as this roller gears with the screw-thread, which in that case performs the office of a ratch, the rise and fall of the tool-holder is thus adjusted.

We have still to explain how the shaft, *i*, of the tool-holder is fixed, so that the drill with which it is armed is made to penetrate the metal. The arrangement for accomplishing this is very ingenious; and if it did not require considerable friction, which it is desirable to avoid, it would be of important application in a great number of cases. It has been seen above, that the journals of the rollers, *t*, are prolonged outwards beyond their supports; it is upon this prolongation that a brake is placed, composed of two brass clasps, *u*, which embrace the journals, fig. 5, and which are worked to lock or unlock them

by means of a thin screw-shaft, *x*, carrying at its lower extremity a small handle. This shaft is cut at the top into two screw-threads—one to the right, the other to the left. Each of these screws works into the brass clasps, *u*, causing them to close or open, according as the small shaft, *x*, is turned in the one direction or the other.

Now, if this brake be very firmly closed, the rollers, *t*, are rendered immoveable; and as they act the part of nuts, and consequently offer a point of resistance to the screw of the tool-bearing shaft, the latter and the drill with which it is armed advance into the metal, which the latter pierces by a distance equal to the pitch of the screw for each turn of the tool. This is the action of the machine when a soft metal or holes of small diameter are pierced. The greatest speed of the tool is $\frac{1}{100}$th of an inch for copper, and about half that distance in piercing iron.

When it is desired to make the tool advance only by a very small distance, it is merely necessary to render the resisting point of the screw slightly moveable. For this purpose, the brake, *v*, is unlocked to a corresponding extent. It will be seen, therefore, that the drill-holder always advances by the same amount, but that this amount is diminished to that extent to which the rollers, when rendered moveable, recede. In this manner the speed of the tool may be varied at pleasure, by rendering the brake more or less firm; so that, when the tool must advance quickly, the brake is strongly compressed, where-

Fig. 1

Fig. 3.

Fig. 5.

Fig. 4.

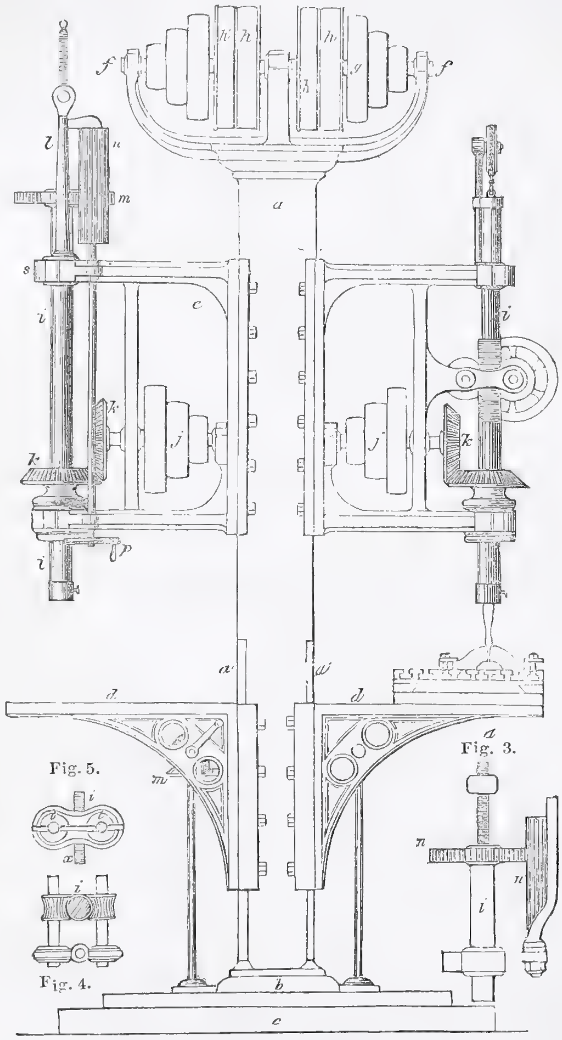
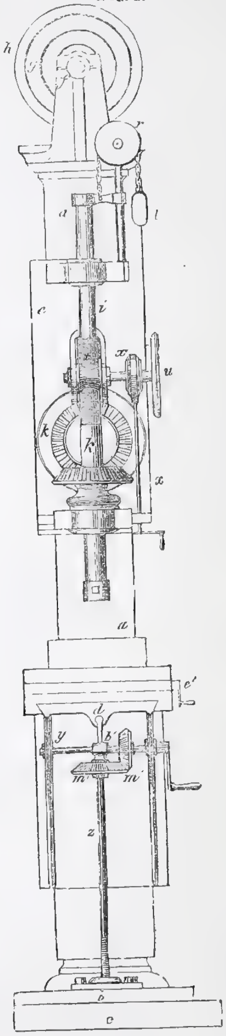


Fig. 2.



as, to retard its progress, the grasp of the brake is relaxed to any required extent.

Moveable Plates.—Among other advantages which ought to be combined in a drilling machine, it ought to admit of receiving, on its plateau, pieces of very different dimensions, and also of fixing them with ease and despatch in their position; this plateau should admit of being moved in every direction, and even of taking, when required, an eccentric movement with reference to the tool-bearing shaft. The arrangement adopted by M. Frey consists in making the plates to be sustained by screws, supported in nuts fixed behind the plate-rest. Thus the brackets of the plates, fig. 2, support in their bearings the shafts, *y*, which in the middle of their length sustain the head of the screw, *z*, which passes through the nut, *b′*. By means of the bevil wheels, *m′*, *m′*, the movement imparted to the shafts, *y*, is transmitted to the screw, *z*, to raise or depress the plates which are supported upon them.

At the side of the plate is a handle, *c′*, mounted at the end of a screw, *d′*, placed under the plate, and which is inserted in a nut. The latter is in one piece with another plate, sliding on the principal plate, and moving as the nut moves, so that it advances or retires the whole length of its slot. A similar movement is given to a second slide-plate, adjusted in the same manner over the first, and this is worked by a small handle, *e′*, placed behind the machine, and operating like the preceding by means of a screw. This second plate may occupy any desired position over the width of the machine, and may be rendered eccentric with reference to the tool-holder.

Such is a short account of the drilling-machine constructed by M. Frey for his own use, and also for other establishments.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER II.

RETROGRESSIONISM—METAPHYSICAL PHILOSOPHY OF GREECE.

We have now to investigate a notion, which, if well-founded, falsifies all that we have said in the foregoing pages. We have used the term "science," in speaking of the mystical symbolism of the primitive world, with some reluctance, for though affording a conception of the universe, it was fundamentally different from modern science in method as in spirit. But there are others who entertain very different views concerning the philosophy of the remotest ages. They maintain that mankind possessed, at some unassigned period, a body of exact and abstract knowledge; in short, a positive philosophy, equal, if not superior, to what we now enjoy. This philosophy, after flourishing for ages, was lost—from what cause is not rightly ascertained—and only a few detached fragments have reached us in the writings of the earliest Greek sages. We, in these days, are painfully rediscovering some part of the heritage of our forefathers.

This doctrine, held by many writers of the present time, is too fearfully momentous to be passed without a searching review. It is, in fact, the very creed of despair. If it be true, mankind, as a body, has, we emphatically declare, no hope. If science does not continually advance, the whole theory of human progression is an idle dream, the fountain at which the noblest of our species have drank inspiration is dried up, and everything grand and heroic vanishes from the earth. Now to the question. If the defenders of retrogressionism (for so we shall call this doctrine) be asked for evidence, they point to the splendid ruins of Nineveh, to the colossal remains of Egypt and India, to the forsaken cities of Guatemala, and the ramparts of North America, and maintain that works so vast and magnificent imply a high degree of mental culture amongst their producers. But we have recently seen that practical art may advance to a great extent without the aid of theory. Now, in the ruins enumerated, we find abundant evidence of regal power, of luxury, ostentation, of empirical industry, and even of artistic taste; but of science not a trace. The most colossal buildings of Egypt appear to have been raised by manual labour, employed without regard to time, to expense, or to life, and aided by simple mechanical contrivances. That complicated machinery which would lead us to infer the existence of mechanical science was wanting, else we should have found it represented in those sculptures which afford us so complete a picture of the details of Egyptian life. But, instead of the steam-engine or the hydraulic press, we see vast bands of harnessed slaves, goaded on by spearmen, dragging enormous stones, or raising them up inclined planes to the place of their destination. The Egyptians were able to foretell eclipses. True, but this was effected, not by mathematical calculation based upon an exact knowledge of the planetary movements, but by observing that eclipses recur within a certain cycle of years, nearly at the same periods. It has been asserted that the Hindoo astronomers were of old acquainted with the moons of Jupiter and the rings of Saturn, and it has been hence concluded that they were acquainted with the telescope, and versed in those branches of optical science implied in its construction. But how does such an influence agree with the following observation? An American missionary, named Stoddart, writing from Oroomiah, in Persia, informs Sir J. Herschel, that he has been able to distinguish the satellites of Jupiter, the crescent form of Venus, the rings of Saturn, and the constituent members of several double stars with the naked eye! It is, again, asserted that, in the oldest philosophical fragments which have been handed down to us, we meet with ideas more accordant with the truth, than in the Greek philosophy of later times. Thus, the Pythagoreans, according to some, were acquainted with the revolution of the earth, with the elliptical figure of the planetary orbits, and with the law of definite proportions, and possessed these views, not as discoveries of their founder, but as remains of Eastern lore. We borrow, in reply, a passage from Whewell:—"If resemblances should be discovered between the assertions of ancient writers, and the discoveries of modern science, the probability in all cases, the certainty in most, is, that these are accidental coincidences; that the ancient opinion is no anticipation of the modern discovery, but is *one guess among many*, not a whit the more valuable because its expression agrees with a truth." Between a guess and a discovery, there is a world-wide difference. It is not sufficient to pick up the jewel truth from the dunghill, and toss it carelessly aside, we must recognise it as a jewel, and hold it fast as such. It is not in surmise, but in demonstration, that science lives and moves and has her being.

"But how does it arise," ask the upholders of retrogressionism, "that in ancient Greek tradition we find the origin of science constantly referred to the East? that Pythagoras and Plato, and other sages also, are said to have acquired the principal part of their knowledge in Egypt or Chaldea? The solution to this question is given in that common tendency of human nature, to seek the origin of everything wonderful and strange in distant regions or remote ages. To the vulgar mind, foreign climes are still invested with a mystery which all the locomotive habits of our age have not entirely shaken off. "It must come from abroad," exclaims the rustic with a shake of his head, as he surveys any unusual production of art or nature. Self-love leads him to believe himself acquainted with whatever exists, or can be produced in his own country, and by referring the unknown object to another land, he excuses his ignorance. From the want of popular education, the greater sway of superstition, and the smaller facilities for travelling, this vague notion attaching to foreign countries must have been far more powerful in ancient Greece than at the present day; and the admitted fact, that certain *arts* were derived from the East, would not unnaturally lead mankind to look in the same direction for the origin of *science* also: for the distinction between art and physical science (as apart from metaphysical dreaming) was not yet clearly drawn—another important argument against the fancied antiquity of the latter. Many of the ancient philosophers travelled in the East. Very true. And vulgar envy solaced itself for their mental superiority by ascribing all, or much, to those travels. "Had I visited Egypt, I should have been as great as you, Democritus, or you, Plato!" The writer has heard similar sentiments brought forward concerning Humboldt, by little souls, who, forsooth, could have equalled him, had they been so fortunate as to travel in Mexico and Peru, where, perhaps, wisdom, like silver, might be had for gathering. And the opinion held of the wisdom of antiquity is but a remnant of the veneration entertained by children for their fathers, to whom weak minds consider themselves as permanently, not temporarily inferior, and transfer this mistaken reverence to the whole past. Thus, then, we see the origin of that tendency which induces popular tradition and ancient authors to seek the origin of science and of human progress in distant regions and in prehistorical ages, and we will beware how we suffer ourselves to be guided in historical research by a feeling born of vulgar astonishment and petty jealousy.

It is further maintained that the marvellous performances by which the Egyptian priests sought to maintain among the people a reputation for supernatural power, were an evidence of high scientific attainments. But the assumption is gratuitous; common jugglery—a native of the East—and a few processes which have since, indeed, received scientific connection, but which were then performed, as well as discovered, empirically, would be quite sufficient. Ordinary jugglers in the middle ages had such "tremendous success," that they were sometimes burnt to death for their pains. And to this day a lurking suspicion of necromancy remains in the minds of many who visit the exhibitions of our "*professors*" of legerdemain. Was Egypt less credulous, or harder to delude?

But it is now time for us to act on the offensive, and inquire of the retrogressionists how such an amount of science could be accumulated at so early a period of the world's history? Was it communicated to man through any supernatural channel? As we have no authenticated example of a scientific revelation, the burden of proof must lie with our opponents. If no help from above was given, how can we, without demonstration, believe that man could, in a few centuries after the

origin of the species, attain a pitch of intellectual elevation, which it has hardly now regained after the continual recorded struggles of more than two thousand years?

Again, if such a body of science were once attained, how was it lost? "By war," reply our opponents; "by the inroads of barbarian enemies." But making all due allowance for the secrecy maintained by the Egyptian priests, which, limiting knowledge to few, would render it more easily lost, and for the absence of the printing-press (which no one has as yet thought proper to discover amidst the ruins of Ipsambul or Copan), had science attained its modern perfection, its possessors would have possessed means of defence, against which barbarian valour would have been impotent. Nay, does not this very confession of the secret, esoteric character of Egyptian learning prove that it could not be true science? Empirical art and mystical symbolism may seek concealment, but science, of its very essence, seeks light, publicity, diffusion. "Secret science" is little better than a contradiction in terms.

Further, we oppose to the notion of a primitive, eastern science, the unchanging nature of the orient. Amidst the rise and fall of empires, and the decline of former splendour, we find now, as in the most ancient historical records, the spiritual tendencies, the habits of thought unaltered. And in those tendencies we find nowhere that desire of theory, that necessity for exact, abstract, co-ordinate knowledge which are met with in the West. Do not those, then, who would have us seek in the East, and in prehistorical ages, for the origin of science, betray an ignorance of its fundamental idea?

Yet more: from the earliest period of which we have any distinct record, science has continued to advance, with various rapidity, but still never losing ground once gained. What should lead us to suppose that its movements were previously of an opposite nature? Suppose we are shown a healthy child, which, we are told, has for the last years been growing and expanding for some years in the ordinary manner. What shall we think if our informant adds, that shortly after its birth it attained at once the stature, proportions, and faculties of an adult, then dwindled down to puny dimensions, and finally recommenced growing? Yet he who tells us a similar story concerning the human race, in fact plays with our credulity in a manner no less impudent. The theory of retrogression entirely sets aside that beautiful and significant analogy between the species and the individual to which we have already alluded. The progress of humanity will doubtless not endure for ever; the race, now but in the outset of its career, will reach maturity and decline, but after that comes no revival. We are perfectly willing to grant that arts formerly possessed may have occasionally been lost—that philosophy may have forsaken her ancient haunts to seek shelter elsewhere. But to uphold the doctrine of retrogression is, in our opinion, to misapprehend the fundamental idea of universal history, no less than of man's intellectual evolution.

These preliminary considerations disposed of, we proceed to notice the second epoch, the inauguration of the metaphysical philosophy in ancient Greece. An entire change "comes o'er the spirit of our dream." Personification is now abandoned; the gods, no longer conceived as one with the natural objects they rule, gradually receive a more distinct and separate existence, though an under-current of the old nature-worship still survives, and fills river, wood, and mountain with spiritual life. The want of theory, the desire to combine and co-ordinate knowledge, is clearly felt. On some of the more simple subjects, positive ideas, such as we now entertain, are formed. The sciences, by degrees, as they obtain a definite constitution, detach themselves one by one from the old stem of general philosophy, or "wisdom," and maintain for the present an independent existence, to be once again reunited. A provisional separation takes place between "moral" and "natural" philosophy, which two departments are now committed to distinct hands, and conducted by opposite methods. Conflicting schools of philosophy arise and contend for supremacy. We are no longer, in surveying this epoch, inconvenienced by a paucity of materials, but may learn from authentic records the doctrines and career of the great thinkers of the age. We find, during the Greek epoch, four successive centres of intellectual activity; the cities of Ionia, and neighbouring Egean Islands, the Greek colonies in Italy and Sicily, Athens, and lastly Alexandria.

The earliest of the Greek philosophers was Thales, a native of Miletus in Asia Minor, one of the so-called seven wise men. He had travelled in Egypt and Chaldea, and possessed a knowledge of mathematics and astronomy, very considerable for the times. He forms a connecting link between the supernatural and the metaphysical periods. His connection with the former is shown by his ascribing a soul to the magnet, whose attractive effects upon iron he was the first to observe. Seeking for the first principle, the beginning of all things, he decided in favour of water, or moisture. A doctrine less absurd than might seem at first glance. He had seen how the presence of moisture is necessary to fertility and life, how animals and vegetables without it wither and perish, how, even in the spiritual culture, civilization, the progress of humanity, advanced most rapidly upon the sea-shore, or on the banks of rivers. Between his scheme and the cosmogonies of Hesiod and Orpheus, a certain affinity is traceable. He translates the poetic mythus into a philosophy scarcely less poetical. In both, the world is begotten by two antagonistic principles, which find in water their synthesis, their identity. Does the modern idea of polarity find in these conceptions its dim foreshadowing? and are the male and female principles from which all proceeded, an image of oxygen and hydrogen, which, according to some modern speculators, typify all polarity, and are the ultimate constituents of all things? But whatever we may deem of the rationality of the doctrines of Thales, we must hail in him the morning star of science, the father of systematic inquiry. He left posterity the maxim, "Know thyself." Wisely commanded, oh! venerable father; but we must first know all other things before that shall become possible. Anaximenes, likewise a Milesian, follows next. Still seeking, like his predecessor, a first principle, he rejects water and adopts air, as more universal, active, life-giving. His mother-tongue had but one term for "air" and "spirit." What wonder if in it he sought for the fountain of all existence! The idea is more plausible than that of Thales. Advance is perceptible. It may be here remarked, once for all, that in the water of Thales, and the air of Anaximenes, we must not view the concrete ponderable matter, enclosable in vessels, but an abstract, half-personified embodiment of the Fertilizing and the Vivifying, the universal Seed and Breath. This is the nature of the Greek mind; it cannot dwell in the concrete; but in all speculation it flies to the abstract, the ideal, and makes its home there. But a further advance is now at hand. Diogenes of Apollonia—not that other Diogenes of dog-memory—follows, and is alike dissatisfied with Thales and Anaximenes. Neither air nor water, however personified and refined by abstraction, appears to him as the universal principle, the beginning of all. Intelligence, therefore, was adopted as the prime source of the universe. Here we see the metaphysical element becoming more definitely consolidated. But traces of the old primary philosophy still survive. Diogenes views the world as a living being, whose respiratory organs are the stars. All the phenomena on the earth's surface, evaporation, magnetism, are due to the breathing of the world animal. And to explain man's superiority over the brute tribes, we are told that holding his head erect he breathes a purer air. With Diogenes ends the earliest or Ionian school of philosophy, called also the physiological, from its habit of seeking in the elements the principle of existence, and of viewing the world as a living organism.

Another school had meantime arisen of different and perhaps of more advanced views. These were the mathematicians, headed by Anaximander of Miletus, the friend, or, according to some, the disciple of Thales. If the latter statement be true, it will be a difficult task to show any filiation of doctrine between them. He is the first philosopher who, distrustful of tradition, committed his views to writing. His mathematical researches were extensive, and he is celebrated as the inventor of the sun-dial, and of geographical maps. His first principle was infinite existence, an exclusively abstract conception, which may not unnaturally be traced to the mathematical tendency of his speculations. It is no uncommon practice with metaphysicians to elevate abstractions, the creation of their own

minds, into actual existences. This infinite existence was immutable, though everything in it was subject to change. He supposed the earth to be situate in the centre of the universe; for being a cylinder, whose base is to its height as one to three, it was retained in its position by the equality of its distances from all the limits of the world. He is considered to have been the first who maintained the immortality of the human soul.

We often meet with the traces of a man, of whom history can give no distinct and satisfactory record, but who, evidently, must have exercised a wide and profound influence over his contemporaries. The very vague and contradictory nature of the traditions concerning Pythagoras proves him to have been a thinker of the highest order. For true to the maxim, "to him that hath shall be given," public opinion attributes unclaimed marvels to such men only whose greatness is manifest. The materials for his biography are plentiful, if we accept all that tradition has collected, but scanty enough upon closer inspection. He was born in Samos, at what period cannot be decided, enjoyed the favour of King Polycrates, visited Egypt and the East, and settled finally in southern Italy. Here, in the city of Croton, he founded a philosophic school, which aimed not only at the attainment of wisdom, but also at political supremacy to some extent, as far as we can judge, on the principle of an aristocracy of intellect.* For a time the attempt proved successful, but at length an insurrection ensued. The Pythagoreans were overpowered, and their chief either perished in the tumult, or died subsequently, a fugitive, at Metapontum. As this illustrious thinker has left us no written account of his doctrines, we need not be surprised at the obscurity in which they are involved. The superstition of after ages viewed him as a worker of miracles, a demi-god (or, as it would be translated into mediæval language, a saint), the son of Apollo, or perhaps an incarnation of that god. Plotinus exalts him as a pagan rival to Jesus Christ. He lectured at the same instant in distant places; he tamed with words the Daunian bear; the water-gods saluted him as he was crossing a river, with other marvels innumerable. All these traditions laid aside, it is certain that he was one of the fathers of mathematical science. He is reputed, further, to have anticipated Copernicus on the solar system, and Dalton on the law of definite proportions. The former opinion may be true, if we consider a conjecture equal to a demonstration; the latter springs from a misconception of the celebrated Pythagorean numbers. As a mathematician, he attached the greatest importance to numbers, which he regarded not merely as symbols, but as the principle and essence of things. 'One' was with him the origin of the universe, because every object may be viewed in its unity. The following significations were ascribed by Pythagoras, or, by his disciples, to numbers. The monad, as the One, is the measure of all things, *mensura, mens;* it is the foundation, unity, nay, it is all things. The dyad is the principle of opposition and plurality. The triad brings back the opposition to total harmony. The tetrad is the symbol of outward perfection ($1 + 2 + 3 + 4 = 10$). The pentad symbolizes the outward senses. The hexad, 2×3, represents the two factors of generation. The heptad, which produces nothing, expresses repose and solitude. The octad is the image of justice and felicity. The ennead has the same function. The decad comprehends and sums up all the simple numbers. The difference between the numerical monad and the real monad is this: *monas rationaliter in numeris, essentialiter in omnibus.* He who, in these reveries on the symbolical nature of numbers, can detect anything like the law of definite proportions, must, indeed, possess the gift of "reading between the lines." Pythagoras is said to have founded the sub-science of harmonics, though the story of his hearing blacksmiths striking a mass of iron with hammers of unequal weight, and being, from the sounds elicited, led to discover musical chords, is obviously a fable. He taught, as is well known, the transmigration of souls, asserting that he had himself existed on earth in earlier ages. Was this doctrine, together with his numerical speculations, derived from the East? We think not, in spite of all apparent similarity. Kindred minds will, without collusion, develop kindred ideas. In Pythagoras, amidst all metaphysical abstractions, and notwithstanding the undoubted advances which he made in positive science, the supernatural is not yet eliminated. Strange that two of the most eminent "mystics" of ancient and modern times, Pythagoras and Swedenborg, should have been so eminently mathematical in their habits of thought! From the Pythagorean school proceeded many of the most eminent astronomers and mathematicians. It was the first upburst of intellectual life in Italy.

* Would an aristocracy of intellect be less haughty, less exacting in its demands upon society, than that of pedigree or property?

With Xenophanes, of Colophon, opens the Eleatic school. He was the inaugurator of philosophical sceptism, the forerunner of Pyrrho. His successor, Parmenides, of Elea, maintained that reason alone is capable of apprehending truth, and that the evidence or the senses is fallacious. Here we have the germ of idealism. He derived the universe from two principles, heat and cold, the former the positive intellectual element, the latter the negative.

INORGANIC CHEMISTRY.

CHAPTER IV.

CHEMICAL ANALYSIS.

THE first step in the examination of any substance, whether occurring in nature or produced artificially, is to ascertain its composition. The art by which this is effected, is *chemical analysis:* an art with which the student should render himself practically familiar before entering upon original research. Nor is a knowledge of analysis less necessary to those engaged in the chemical arts and manufactures. By its means alone, the dyer, calico-printer, bleacher, soap-boiler, glass-maker, brassfounder, &c., are enabled to ascertain the actual quality and value of the materials they employ. Nothing surely need be added to convince our readers of the importance of the following chapters, however uninviting they may appear.

A compound body, except it be of the first order, may be resolved either into its *ultimate* components, that is, the simple elements of which it is formed, or into compound bodies of a lower order, its so-called *proximate* compounds. Thus the ultimate constituents of green vitriol, are iron, oxygen, sulphur, and hydrogen. Its proximate constituents—the bodies of which it is more immediately composed—are protoxide of iron, sulphuric acid, and water. The ordinary object of analysis, at least as far as inorganic matter is concerned, is to detect the proximate ingredients of the body in question, from which the ultimate constituents may be deduced without further experiment. Thus, recurring to our example of green vitriol, if we have ascertained that it consists of protoxide of iron, sulphuric acid, and water, our task is completed, since the composition of these three bodies is already established. In compounds of the first order, oxides, chlorides, &c., the distinction between ultimate and proximate components cannot exist.

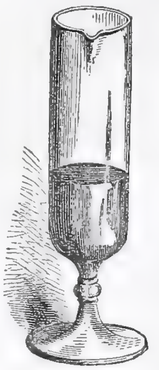
In ascertaining the constitution of any substance, we may ask simply, what are the elements here present? or we may go further, and endeavour to determine the quantity of each. On this consideration depends the important distinction of analysis into *qualitative* and *quantitative;* the latter of which always presupposes the former. In other words, we must ascertain what substances are present, before attempting to find their quantity by weight or volume.

ANALYTICAL MANIPULATIONS AND APPARATUS.

The ordinary procedure in qualitative analysis is to add to the substance in question some body which may show the presence of the elements sought for, by a change of colour, the formation of a precipitate, or some other phenomenon ensuing. The body thus added is called a *test*, or *reagent*, and the change produced on its addition is the *reaction.* Reagents may be either general or special. The former decide on the presence or absence of a class of bodies, whilst the latter detect individual substances. Thus, if sulphuretted hydrogen, passed into a solution, forms a precipitate, we know that one or more of a certain class of metals must be present. If iodide of potassium,

added to the same solution, give a bright scarlet precipitate, we know that the metal present is mercury, and that it exists in the form of a protosalt. Both the reagent and the substance to be examined are usually employed in a liquid state, the solvent employed being pure distilled water. Bodies insoluble in water are dissolved in acids, according to their nature. Test solutions should be moderately dilute; they are rendered perfectly clear by filtration, and preserved in well-stoppered or corked bottles. The upper part of such test-bottles as are not constantly in use, should be covered with a paper or leather cap, to prevent the accumulation of dust upon the lip, and all should be frequently examined and wiped.

The reagent and the substance under examination, are generally brought in contact in a test-tube, a small beaker, or a test-glass, shown in the annexed figure.



The two former offer the advantage that heat may be applied, which is often desirable. If the quantities operated upon are minute, the mixture may be made upon a slip of flat glass, a watch glass, or a flat piece of porcelain, the test being added with a glass rod. The reaction may often be more distinctly observed if produced upon a flat surface, and white porcelain affords peculiar facilities in judging of the colour of a precipitate. In almost all cases the reagent should be introduced drop by drop. If, in neglect of this precaution, a large quantity of the test-liquid be added at once, the reaction frequently fails, and in other cases is rendered less distinct. The result does not always ensue instantaneously; hence, after adding a precipitate, it is well to let the mixture stand aside for a time, before coming to a decision. The reaction is often promoted by shaking the test-tube, or stirring with a clean glass rod.

The phenomena produced on the addition of a reagent are of various kinds. Sometimes a solid body separates, which is termed a precipitate, even though, from its low specific gravity, it rises to the surface or remains suspended in the liquid. Sometimes there ensues effervescence—an escape of gas in the form of bubbles. Sometimes, again, the colour of the liquid is changed, permanently or transiently, or a characteristic odour is given off.

Precipitates are distinguished by their colour and texture. In the latter point of view, they may be either pulverulent, flocculent, curdy, gelatinous, or crystalline; examples of all which will be given below. Sometimes, if the solution be extremely dilute, or the amount of the body sought for very small, there is no visible deposit of solid matter, but the liquid becomes slightly opaque, milky, or, as it is technically called, opalescent.

REAGENTS.

All substances employed in testing, should be, if possible, absolutely pure, as the presence of foreign bodies, even in a very minute proportion, may seriously interfere with the result. The following are of frequent use, and should be kept at hand in the laboratory.

Acids :—

Sulphuric.	Hydrocyanic.	Oxalic.
Nitric.	Hydrosulphuric.	Tartaric.
Hydrochloric.	Silico-fluoric.	
Sulphurous.	Acetic.	

*Bases :—*Caustic potash, soda and ammonia, hydrates of baryta and lime.

Salts : Carbonates of potash, soda, and ammonia; oxalates of potash and ammonia; yellow and red ferrocyanides of potassium; chlorides of ammonium, barium, and platinum; nitrates of potash, silver, mercury, and baryta; phosphate of soda; iodide of potassium; chromate of potash; chlorate of potash; acetate of lead; hypochlorite of soda; protochloride of tin; chloride of lead; sulphate of lime; molybdate of ammonia; sulphate of indigo; infusion of galls; starch; litmus and turmeric papers; alcohol; distilled water; bromine.

Other substances, less frequently needed, will be incidentally mentioned.

A few remarks on the impurities likely to occur in these reagents will be useful to the student. Sulphuric acid is apt to be contaminated with nitric acid, sulphate of lead, arsenious acid, and oxide of tin. The first of these impurities is detected by heating the acid with a little sulphate of indigo, the colour of which is destroyed by nitric acid. If lead is present, the acid is rendered turbid on the addition of water. It may then be allowed to settle, and the clear liquid decanted off for use. Arsenious acid and oxide of tin give a precipitate with sulphuretted hydrogen. Nitric acid often contains sulphuric acid and chlorine. If the former is present, the dilute acid gives a white precipitate with nitrate of baryta, whilst the latter forms a white precipitate with nitrate of silver. The hydrochloric acid of commerce is so impure as to be worthless for analytical purposes. It should be prepared in the laboratory, according to the directions given in a former chapter. Sulphurous acid, which is always used in the state of solution, is apt to be contaminated with sulphuric acid if exposed to the atmosphere. Tartaric and oxalic acids are purified by repeated crystallization. If the latter deliquesce, it contains nitric acid.

Caustic potash usually contains oxide of iron, carbonate and sulphate of potash, and chloride of potassium. The former subsides in brown flakes, if the solution is allowed to stand. The sulphate is deposited, if the liquid is concentrated to sp. gr. 1·250. To remove the two other impurities, the mass is treated with strong alcohol, in which they are nearly insoluble.

Ammonia, to be absolutely pure, should be redistilled at a gentle heat, condensing the evolved gas in pure cold water. Hydrate of baryta may contain traces of undecomposed nitrate and silica from the crucible. Carbonates of potash and soda are contaminated with sulphates and chlorides, alumina and silica. Chromate of potash occasionally contains sulphate and carbonate of potash, the former of which occurs also as an impurity in ferrocyanide of potassium. Iodide of potassium contains alkaline chlorides, and carbonate of potash. Chloride of ammonium contains sulphates of ammonia and soda, and chloride of sodium. It is purified by recrystallization. Nitrate of silver often contains nitrates of copper, potash, and lead. The first is detected by ammonia, which turns it blue; the last is precipitated by sulphuric acid. It should always be purchased in crystals, not in sticks or rolls. Water should neither be rendered turbid by nitrate of silver (chlorides), chloride of barium (sulphates), oxalate of ammonia (lime), nor lime-water (carbonic acid). It should have no action upon test paper, and leave no residue if evaporated to dryness upon a piece of platinum foil.

CLASSIFICATION OF METALLIC OXIDES FOR ANALYTICAL PURPOSES, AND BEHAVIOUR WITH TESTS.

I. Bases not precipitated by sulphuretted hydrogen, or alkaline hydrosulphates.

a. Not precipitated by carbonate of soda:—Potash, soda, lithia, ammonia.

1. Solutions of potash, if moderately concentrated, give a pale yellow crystalline precipitate with *chloride of platinum*, and a white crystalline precipitate with *tartaric acid*. Both are rendered more distinct by stirring, and by the addition of a little alcohol. An alcoholic solution of *carbazotic* acid gives a pale yellow precipitate, even in dilute solutions of potash.

2. Soda solutions, if concentrated, give a gelatinous precipitate with *fluosilicic* acid, and with the *antimoniate of potash*. The presence of this alkali is usually detected by means of the blowpipe. (See Blowpipe.)

3. Lithia is precipitated by the *ammonio-phosphate of soda*, but it is most easily recognized by the aid of the blowpipe.

4. Ammonia is very similar in its behaviour to potash, from which it may be distinguished by the addition of caustic *potash*, or slaked *lime*, when ammoniacal fumes are evolved. These are recognized by the dense white fumes produced on presenting to them a rod moistened with hydrochloric acid, and by their action upon red litmus paper.

b. Precipitated by carbonate of soda:—Baryta, strontia, lime, magnesia.

The three former of these earths give white precipitates with dilute *sulphuric* acid, and with soluble *sulphates*. A solution of sulphate of lime precipitates baryta and strontia; a solution of sulphate of strontia, baryta alone. *Bichromate of potash* precipitates baryta, but not strontia. The latter earth is easily detected with the blowpipe.

Lime forms a white precipitate with *oxalate of ammonia*, even if the solutions are very dilute. It increases on standing.

Magnesia forms bulky, flocculent, white precipitates with caustic *potash*, *ammonia* (resoluble in *muriate of ammonia*), and *ammonio-phosphate of soda*. It gives no precipitate with sulphuric acid, nor with soluble oxalates.

II. Oxides precipitated by hydrosulphate of ammonia, but not by sulphuretted hydrogen from an acid solution.

Alumina.	Tantalic acid.
Cerium oxide.	Titanic acid.
Chrome sesquioxide.	Thoria.
Cobalt oxide.	Uranic oxides.
Glucina.	Vanadic oxide.
Iron oxides.	Yttria.
Lantanium oxide.	Zinc oxide.
Manganese oxides.	Zirconia.
Nickel oxide.	

Besides the chromic, manganic, and permanganic acids.

1. Alumina gives, with caustic *potash*, a bulky precipitate, easily soluble in excess; with *ammonia* and its carbonate, a similar precipitate, insoluble in excess. The presence of muriate of ammonia has no influence, which distinguishes alumina from magnesia. (See also Blowpipe.)

2. Ceric oxide gives, with caustic *potash*, a bulky white precipitate, insoluble in excess. Its behaviour with ammonia is similar.

3. Sesquioxide of chrome gives, with caustic *potash*, a green precipitate, soluble in excess, but reprecipitated by muriate of ammonia, and by long boiling. If fused with saltpetre, it is converted into chromic acid, and may then be detected as shown below. (See also Blowpipe.) Its precipitate with *hydrosulphate of ammonia* is a greenish grey.

4. Cobalt oxide gives, with caustic *potash*, a blue precipitate, insoluble in excess; it turns green on exposure to the air, and, if boiled, generally a pale red; with *ammonia*, a blue precipitate, soluble in excess, and in muriate of ammonia. The *carbonate of ammonia* gives, in neutral solutions, a pink precipitate. (See Blowpipe.)

5. Glucina yields, with caustic *potash*, a white bulky precipitate, soluble in excess. The carbonates of potash and ammonia form also precipitates, soluble in excess, a circumstance which distinguishes glucina from alumina. If bodies containing alumina and glucina are contaminated with non-volatile organic matter, they must be exposed to a red heat, and the residue exhausted with hydrochloric acid. The usual tests may then be applied to this solution.

6. Iron. The protoxide gives, with *potash* and *ammonia*, a dirty white precipitate, which rapidly turns green and brown on exposure to the air. *Alkaline carbonates* produce a very similar precipitate, but, as well as caustic ammonia, take no effect if ammoniacal salts are present. *Ferrocyanide of potassium* gives a white precipitate, which soon turns blue (from formation of peroxide), and *ferridcyanide*, a deep blue at once.

The peroxide forms, with *alkalies* and their *carbonates*, a brown red precipitate, insoluble in excess; with *ferrocyanide of potassium*, a deep blue precipitate (*prussian blue*); with *ferridcyanide*, nothing; with *sulpho-cyanide* of potassium, a beautiful crimson tinge, even in the most dilute solutions; with infusion of galls, a deep blue-black precipitate (ink). Non-volatile organic matter masks the action of most of these tests, and should be previously destroyed.

7. Lantanium oxide yields, with *potash*, a pinkish-white precipitate, insoluble in excess; with *fluoride of sodium*, a white flocculent precipitate; with *ammonia*, a bulky white precipitate, insoluble in excess, and in muriate of ammonia.

8. Manganese. The protoxide gives, with *potash*, a faintly reddish-white precipitate, which turns brown on exposure; with *ammonia*, the result is similar. *Alkaline carbonates* yield a white precipitate, which does not change colour, and is slightly soluble in muriate of ammonia. *Hydrosulphate of ammonia*, a pale flesh-coloured precipitate, insoluble in alkalies; blackened by exposure. *Ferrocyanide of potassium*, a pinkish-white precipitate, soluble in free alkalies.

The sesquioxide and peroxide give blackish-brown precipitates with *alkalies* and *alkaline carbonates*. (See also Blowpipe.)

9. Nickel oxide gives, with *potash*, an apple-green precipitate, insoluble in excess, but soluble in carbonate of ammonia; with *ammonia*, a green precipitate, soluble in excess, but reprecipitated by potash.

10. Tantalic acid forms, with *potash*, a white precipitate, soluble in excess. If fused with potash, the acid dissolves in water, and the solution gives, with hydrochloric acid, a precipitate, insoluble in excess. (See Blowpipe.)

11. Titanic acid. If an alkaline titanate is dissolved in muriatic acid, and a piece of zinc placed in the solution, it becomes blue, and deposits a blue precipitate, which ultimately turns white.

12. Thoria gives, with caustic *potash*, a white precipitate, insoluble in excess, which distinguishes it from alumina and glucina. From magnesia it may be distinguished by aid of ammonia, which precipitates it even if muriatic acid be present.

13. Oxides of uranium. The peroxide gives, with *caustic alkalies*, an orange precipitate, insoluble in excess; with *alkaline carbonates*, a pale-yellow precipitate, soluble in excess, especially if a bicarbonate be employed; with *ferrocyanide of potassium*, a bright-red brown; with *tincture of galls*, chocolate brown. The green oxide, $U_3\ O_4$, (formerly regarded as protoxide,) gives, with *alkalies*, a brown precipitate, insoluble in excess; with *alkaline carbonates*, a greenish precipitate, soluble in excess.

14. Vanadic oxide gives, with *potash*, a greyish-white precipitate, soluble in excess (solution brown); with *alkaline bicarbonates*, a greyish-white precipitate, soluble also in excess (solution blue); with *tincture of galls*, a blue so intense as to appear black, if the liquid be not very dilute.

15. Yttria gives, with *alkalies*, a bulky white precipitate, insoluble in excess; with *carbonate of ammonia*, a white precipitate, soluble in excess; with *oxalic acid*, a bulky white precipitate, soluble in hydrochloric acid.

16. Zinc oxide yields, with *alkalies*, a white precipitate, soluble in excess; with *carbonate of potash*, a white precipitate, insoluble in excess, but soluble in potash, ammonia, and ammoniacal salts.

17. Zirconia produces, with *alkalies*, a bulky white precipitate, insoluble in excess; with *oxalic acid*, a bulky precipitate, soluble in large excess of hydrochloric acid.

III. Oxides (basic) precipitated from acid solutions by sulphuretted hydrogen:—

Antimonic oxide.	Molybdenum, oxides of.
Bismuth oxide.	Osmic oxide.
Cadmic oxide.	Palladious oxide.
Copper, oxides of.	Platinum, oxides of.
Gold oxide.	Rhodium oxide.
Iridic oxide.	Silver oxide.
Lead oxide.	Tellurium oxide.
Mercury, oxides of.	Tin, oxides of.

Besides the following acids: arsenious, arsenic, antimonious, antimonic, molybdic, osmic, selenious, tungstic, vanadic.

1. Antimonic oxide gives, with *caustic* and *carbonated alkalies*, a white precipitate, soluble in excess of caustic potash only; with *hydrosulphate of ammonia*, an orange precipitate, soluble in excess, but reprecipitated by acids; with *sulphuretted hydrogen*, an orange-red precipitate, soluble in alkaline sulphurets, in potash, and in boiling hydrochloric acid. Oxalic acid and phosphate of soda give also dense white precipitates. A bar of metallic zinc throws down metallic antimony as a black powder. The reactions of antimonic salts are much modified by the presence of organic matter, as will be more particularly shown in the chapter on Toxicology.

2. Bismuth gives, with *alkalies* and their *carbonates*, a white precipitate, insoluble in excess; with *sulphuretted hydrogen* and *hydrosulphate of ammonia*, a black precipitate; with *chromate*

of potash, a yellow precipitate, soluble in nitric acid. Solutions of bismuth are rendered turbid by water, except a large excess of acid be present. A bar of zinc precipitates metallic bismuth as a black powder.

3. Cadmic oxide gives, with *potash*, caustic and carbonate, a white precipitate, insoluble in excess; with *ammonia*, a white precipitate, very soluble in excess; with *carbonate of ammonia*, a white precipitate, insoluble in excess, and in muriate of ammonia; with H.S. and *hydrosulphate of ammonia*, a yellow precipitate.

4. Copper. The suboxide gives, with *potash*, a yellowish precipitate, turning black on exposure; with *ammonia* in excess, a colourless liquid, which gradually becomes blue. The protoxide forms with *potash* a blue precipitate, insoluble in excess, which turns black on boiling; with *ammonia*, a blue precipitate which dissolves in excess, forming a beautiful violet solution; with *ferrocyanide of potassium*, a chestnut-brown, even in highly dilute solutions; with *iodide of potassium*, a white precipitate, soluble in excess. A rod of polished iron, placed in a cupric solution, becomes coated with red metallic copper. Both the oxides of copper give black precipitates with H.S. and hydrosulphate of ammonia.

5. Gold. Perchloride of gold yields, with *ammonia*, a yellow precipitate; with a mixture of *perchloride* and *perchloride of tin*, a purplish-red tinge, and ultimately a violet precipitate; with *sulphate of protoxide of iron*, a purple tint, followed by a dark-brown precipitate. In neutral solutions of gold, sulphurous acid produces a blue tint, and on boiling deposits metallic gold.

6. Iridic oxide gives, with *potash*, a very slight brown precipitate. The liquid, on standing, becomes blue.

7. Lead oxide produces, with *potash*, a white precipitate, soluble in large excess; with *ammonia* and *alkaline carbonates*, a white precipitate, insoluble in excess; with H. S. and *hydrosulphate of ammonia*, a blackish-brown precipitate: with *iodide of potassium*, a yellow precipitate, soluble in excess; with *hydrochloric acid* and *soluble chlorides*, a white precipitate, soluble in excess of water; with *chromate of potash*, a yellow precipitate, insoluble in dilute nitric acid, but soluble in potash; with *sulphuric acid* and *soluble sulphates*, a white precipitate. A rod of zinc precipitates metallic lead in shining scales and spangles.

8. Mercury. Suboxide of ammonia gives, with *potash* and *ammonia*, a black precipitate, insoluble in excess; with *carbonate of potash*, a yellow precipitate, which turns black when heated; with *infusion of galls*, a light-yellow precipitate. The protoxide produces, with *potash*, a yellowish-red precipitate; with *ammonia* and its *carbonate*, a white precipitate; with *iodide of potassium*, a brilliant scarlet. With metallic *copper* both the oxides are reduced, and form a white spot. If a drop of any liquid containing mercury be placed upon a surface of polished gold, and the gold be touched under the drop with the point of a needle or a penknife, a brilliant white spot of metallic mercury will instantly appear. If a strong solution of iodide of potassium be added to a minute portion of any of the salts of mercury, placed on a clean bright copperplate, the mercury is immediately thrown down in the metallic state, appearing as a silvery stain on the copper.

9. Molybdenum. Molybdous oxide gives, with *alkalies*, a deep-brown precipitate, insoluble in excess; with *alkaline carbonates*, a precipitate of the same tint, soluble in excess. The reactions of molybdic oxide are very similar. Both are most easily recognized by means of the blowpipe.

10. Osmic oxide gives, with *potash*, a black, and with *ammonia* a brown precipitate; with H. S. and *hydrosulphate of ammonia*, a yellow precipitate. The salts of osmium are characterized by their property of giving off, when boiled with nitric acid, the offensive odour of suboxide of osmium.

11. Palladious oxide forms, with *potash*, a yellowish-brown precipitate, soluble in excess; with *cyanide of mercury*, a gelatinous yellowish-white precipate, which, on standing, turns almost white, and is soluble in hydrochloric acid. It is formed only in neutral solutions.

12. Platinum. Protoxide of platinum gives no precipitate with *potash*; with *ammonia*, if hydrochloric acid be present, a green crystalline precipitate; with *alkaline carbonates*, a brown precipitate, the supernatant liquid being of a brownish-red colour, and finally turning black; with *iodide of potassium*, a dark brownish-red colour, and ultimately a black precipitate. The peroxide gives, with *potash* and *ammonia*, a yellow precipitate, insoluble in acids; with *subnitrate of mercury*, a yellowish-red precipitate.

13. Rhodium oxide gives, with *potash*, and with *alkaline carbonates*, on boiling, a gelatinous yellowish-brown precipitate. If muriatic acid be added, and the solution evaporated to dryness, the residue, when dissolved in water, acquires a pink colour.

14. Silver oxide forms, with *potash*, a brown precipitate, insoluble in excess, but soluble in ammonia; with *carbonate of potash*, a white precipitate, soluble in ammonia; with *ammonia*, a brown precipitate, very soluble in excess; with *hydrochloric acid* and *soluble chlorides*, a white precipitate, blackened by sunlight, insoluble in acids, soluble in ammonia; with *iodide of potassium*, a pale yellow precipitate, soluble in excess, whitened by ammonia, insoluble in dilute hydrochloric acid.

15. Telluric oxide gives, with *alkalies* and their *carbonates*, a white precipitate, soluble in excess; with H. S. and *hydrosulphate of ammonia*, a brown precipitate, soluble in alkaline sulphurets. (See also Blowpipe.)

16. Tin. Protoxide of tin gives, with *potash*, a white precipitate, soluble in excess; the solution deposits metallic tin, if heated; with *ammonia* and *alkaline carbonates*, a white precipitate, insoluble in excess; the sulphurets are brown, and dissolve in alkaline sulphurets. The peroxide gives, with *alkalies*, a white precipitate, somewhat soluble in excess; with *carbonate of potash*, a white precipitate, soluble in excess. The sulphurets are yellow, soluble in alkalies, alkaline carbonates, and boiling hydrochloric acid.

It may be here remarked, that of the precipitates produced by sulphuretted hydrogen, in solutions of the oxides of this class, those of antimony, gold, iridium, molybdenum, platinum, tellurium, and tin, are soluble in alkaline sulphurets, whilst those of bismuth, cadmium, lead, mercury, osmium, palladium, rhodium, and silver, are insoluble. Sulphuret of copper is soluble in excess of hydrosulphate of ammonia, but not in sulphuret of potassium.

THE SCIENCE OF PHRENOLOGY.

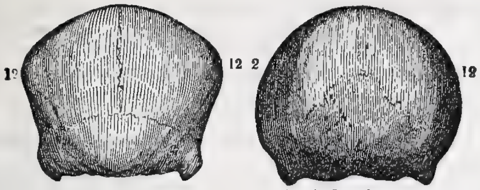
ORDER I.—FEELINGS.

Genus II.—Sentiments.—(*Continued.*)

12. Cautiousness.—The organ of Cautiousness is situated nearly in the middle of the parietal bones. The following is Dr. Gall's account of its discovery:*—At Vienna I was acquainted with a prelate of excellent understanding, and considerable intellect. Some persons had an aversion to him, because, through fear of compromising himself, he infused into his discourses interminable reflections, and delivered them with insupportable slowness. In conversation, it was very difficult to bring him to a conclusion. He was continually pausing in the middle of his sentences, and repeating the beginning of them two or three times before proceeding farther. A thousand times he exhausted my patience. Never in his life did he happen, by any accident, to give way to the natural flow of his ideas, but would constantly recur to what he had already said, and consult with himself whether he could not amend it in some point. He acted just as he conversed. He prepared, with infinite precautions, for the most insignificant undertakings, and every connection was subjected to the most rigorous examination before forming it. This case alone, however, would not have arrested my attention; but this prelate happened to be connected, in public affairs, with a councillor of the Regency, whose external irresolution had procured for him the nickname of *Cacadubio*. At the examinations of the public schools, these two individuals sat by the side of each other, and my seat was directly behind them, so that I had an excellent opportunity of observing their heads. What particularly struck me was, that each head was

* Gall's Works, vol. iv., p. 195.

very broad in the upper, lateral, and hind parts. This extraordinary breadth, coinciding with the peculiar character of these two men, whose qualities and faculties were very different, and who resembled each other only in their circumspection, and in the conformation of their head, suggested to me the idea, that irresolution, indecision, and circumspection, might be connected with a large development of certain parts of the brain. In a very short time my reflections on this quality, and the new facts that were presented, converted my presumptions into certainty.



Large Cautiousness. Small Cautiousness.

This sentiment prompts animals and man to take care. In due quantity, it makes us apprehend danger and consequences, and gives prudence; in large proportion, however, it occasions doubts, irresolution, uncertainty, anxiety, and the host of hesitations and alarms expressed by the word *but*; it also disposes to seriousness, melancholy, and sometimes to suicide from disease. It acts in those animals which place sentinels, and in those which, though they see by daylight, do not dare to seek their food except by night: it may be effected in a way called *fear*. Its deficiency disposes to levity and carelessness of behaviour; the other faculties not being restrained by its presence, act according to their own natures and strength, without any shade of reserve or timidity to obscure their functions.

Some very singular instances of the excess of Cautiousness are given in Dr. Gall's works. I knew (says he) a very rich man, of distinguished talents, and perfectly sound in his mind in every other respect, who was plunged into the deepest despair whenever the conversation turned on any topic connected with his fortune. He saw nothing but misfortunes and disasters. He often shed bitter tears, and thought of destroying himself. At the time of the entrance of Louis XVIII. into Paris, he had an air-gun in his house. " Some wretch," he said to himself, " may fire on the king; the crime will give rise to domiciliary visits; they will find the gun in my house, and will believe me the author of the deed." He broke the weapon in pieces, and threw it away. Still new perplexities arose. " Some years hence, in cleaning out the dirt, they will find these broken bits; all the accidents that have taken place, all the crimes that have been committed by means of air-guns, will be imputed to me." He could rest no longer, till he had collected all the pieces he had thrown away. Subsequently, he broke up his pocket pistols, enveloped the fragments in some paper, and threw them into a remote street. Still more troubles. " Might not my address be written on this paper! If they find it, what horrible suspicions will be excited against me!"*

Nations differ in the extent of development in this sentiment as well as individuals. The lively and thoughtless manner of the Irish people, in whom this organ is but comparatively moderate, affords an excellent contrast to the staid sobriety and caution of the Scots, in whom it is generally large; while the reflecting Englishman, and the volatile Frenchman, indicate an equally broad contrast.

A full development of this organ is essential to a prudent character. With this agrees the testimony of Solomon:—" The prudent man foreseeth the evil, and hideth himself; but the simple pass on, and are punished."

Persons in whom this sentiment is largely developed, are seldom rapid in answering questions. We knew a Quaker, many years since, who could rarely be brought to answer a question directly. He generally evaded the question, by putting in turn a question to the querist. On one occasion, a bet was made between two gentlemen: one contending that he would so frame his question, that an answer *yes* or *no* should be given; the other contending against it. Upon which, going up to the Quaker merchant, the gentleman on the affirmative side said, " Pray, sir, can you tell me if the mail has come in?" " Why, friend, dost thee expect any letters?" was the reply. The wager was lost.

* Gall's Works, vol. iv., p. 201, 202.

In the natural history of this sentiment, Dr. Gall remarks that persons with a large development of the faculty, anticipate all possible dangers, all the fortunate and unfortunate events in their enterprises; they ask advice of all, and then even are undecided. They hold to the adage, that of a hundred misfortunes that befall us, ninety-nine arise from our own faults. Such persons never break anything, and they may pass their lives in pruning trees, or in working with edge-tools without once cutting themselves. If they see a vessel placed near the edge of a table, their nerves shrink. Large sums of money they are never guilty of losing. Finally, they are a standing subject of criticism to less considerate people, who look on their forebodings as extravagant, and their precautions as trifling and absurd.

When this organ is excessively developed, it produces doubt and irresolution, and incapacitates its recipient for any vigorous and decisive conduct. Fear takes possession of the mind, and if it be combined with Destructiveness and small Hope, it leads to melancholy, insanity, and suicide.

Among the lower animals, it is generally larger in the female than in the male. Dr. Gall was much attached to the study of natural history, and often went out to snare and kill small animals. On one of these occasions, he states, that of twenty squirrels killed, not one female was found among them, although it was not the season for attending their young. Of five hundred bears killed in Virginia, only two were females. Among goats, the leader is always a female.

At the destruction of the wolves in France, wherein nearly two thousand were destroyed, little more than one-fourth of them were females. So cautious are female animals, that Capt. Franklin mentions in his voyage to the Arctic regions:—" Although I made inquiries extensively among the Indians, I never met with but one who had killed a she-bear with young in the womb."

We have now gone over those particular organs which are classed by phrenologists as belonging to the lowest rank, and we cannot but have perceived that even in the merely animal feelings, man is every way superior to the brutes.

All the animal propensities are in themselves good. To abuse them is not only an offence against the allwise and good giver, but an absolute punishment we voluntarily inflict upon ourselves. To live in this world without abusing our lower faculties, Christianity must be called to our aid. All the efforts of man are vain, if they have not truth for their guide. To put man in possession of the requisite power for preventing his lower propensities gaining the ascendancy, the Creator has endowed him with superior religious and moral sentiments; the first of which we shall direct your attention to is—

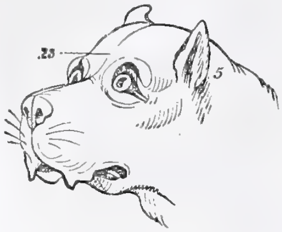
13. Benevolence.—The organ of Benevolence lies on the upper and middle part of the frontal bone. This part of the forehead is much higher in the bust of Oberlin than in that of Pope Alexander VI., of whom portraits are given at pp. 474, 475, Vol. I. The skulls of Caribs are flatter than those of Hindoos in the same situation.

This feeling differs widely both among children and adults. Some are complete egotists in all they do, and think of themselves alone; others excel in goodness, and devote their lives to the relief of the poor and the afflicted. Whole tribes are mild and peaceable, whilst others are warlike and cruel.

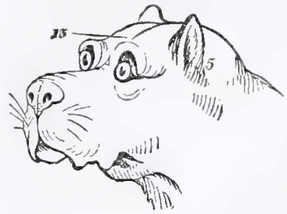
The feeling of benevolence also exists among animals. Several species are naturally meek and good-natured, as the roe and sheep, whilst others are savage and mischievous, as the chamois and tiger. Some dogs, horses, monkeys, &c., are mild and familiar, whilst others of the same kind are bad-tempered, fierce, and intractable.

In mankind, the feeling is greatly ennobled, and its sphere of activity augmented. It produces kindness, benignity, benevolence, clemency, equity, urbanity; in short, it leads to the fulfilment of the great commandment, *Love thy neighbour as thyself.*

Dr. Gall thus relates the history of the discovery of this organ:*—"One of my friends used often to say to me, 'As you are engaged in the researches of the external marks which indicate the qualities and faculties, you ought to examine the head of my servant Joseph. It is impossible to find goodness in a higher degree than in this boy. For more than two years that he has been in my service, I have seen nothing in him but benevolence and gentleness.' This is astonishing in a young man, who, without any education, has grown up in the midst of an ill-bred rabble of servants.



13 Benevolence large.
5 Combativeness small.



13 Benevolence small.
5 Combativeness large.

"Though at this period I was very far from placing what is called a good heart in the brain, and consequently from seeking a mark of it on the head, the repeated solicitations of my friend at length awakened my curiosity. I recalled to my recollection the constant conduct of a young man whom I had known from his tenderest childhood, and who distinguished himself from his numerous brothers and sisters by the goodness of his heart. Though he passionately loved the sports of his age, and his greatest pleasure was to scour the forest in pursuit of birds' nests, as soon as one of his brothers or sisters was sick, a more irresistible inclination kept him at home, and he bestowed on the patient the most assiduous attentions. When there were distributed to the children grapes, apples, cherries, he had always the smallest part, and rejoiced to see the others better provided for than himself. He was never better pleased than when anything agreeable happened to those he loved. In this case, he often shed tears of joy. He took care of sheep, dogs, rabbits, pigeons, birds, and when one of his birds died, he wept bitterly, which never failed to draw on him the ridicule of his companions; and even now, benevolence and goodness are the distinctive character of this individual. His character has certainly not taken this turn from education. On the contrary, others in regard to him have pursued a conduct which should have produced an opposite effect. I began to suspect, therefore, that what is called a good heart, is not an acquired quality, but innate.

"At the same time, I spoke of the goodness of heart, so highly extolled, of the domestic Joseph, in a numerous family. 'Ah!' interrupted the eldest daughter, 'our brother Charles is precisely the same. You must really examine his head. I cannot tell you how good a boy he is!' &c. &c.

"I had, therefore, in sight three subjects, whose goodness of character was well acknowledged. I took casts of all three. I put their busts side by side, and examined them till I found the character common to these three heads, otherwise very differently formed. In the interval I had applied myself to similar subjects in schools, families, &c., in order to be prepared to multiply and rectify my observations. I also extended these observations to animals, and I collected, in a short time, so great a number of facts, that there is no quality, or fundamental faculty and organ, whose existence is better established than Benevolence, and the organ on which it depends."

"Is man born really good or evil?" (asks Dr. Gall, Works, vol. v., p. 158.) This question has distracted and divided theologians and metaphysicians long enough, and has never been fairly and philosophically examined, until the phrenologists took it in hand.

Theologians have viewed it through the trammels of creed, and as there was a greater or less degree of the sentiment in themselves, so have their views been tinged with their own peculiarities. If they had studied it from the grand truth, *God is Love*, they must have been led to the conclusion, that the creature whom He made in his own image, after his likeness, and who, when first introduced to the beauteous earth, was pronounced VERY GOOD, could only have been originally as pronounced. If he fell (we stop not to inquire by what means), and indulged in the opposite disposition, his organization would become more and more deteriorated, as he descended farther and farther from goodness, and evil would increase as it tainted his descendants—it being a philosophical as well as a religious truth, that the sins of the parents descend to the children, to the third and fourth generation. And so must it ever be where there is nothing but evil and vicious example. The child will always emulate the sire, and hence the necessity of such an example, and of such a system of national education, as shall wipe off the foul evil which has so long degraded and debased the human character.

The Creator has stamped the image of his goodness on the creature He has made, and it requires only that man follow Him and learn of Him to be refilled with this godlike virtue. But neglected and oppressed as the great mass of the people have been by those who had the government—or rather misgovernment—of them; degraded by serfdom, and rendered ferocious by sanguinary laws; accustomed to see men hung up as dogs, and their fellow-creatures butchered to gratify the insane ambition of kings and conquerors, why should it be wondered at, that goodness and benevolence have been almost suffocated, and cruelty, vengeance, and destructiveness encouraged, by the fearful examples so constantly before their eyes? We ought not to expect to "gather grapes of thorns, or figs of thistles." The only marvel in the minds of the reflecting is, that in spite of all this hanging, fighting, burning, and wholesale destruction of men's lives, benevolence still asserts its influence, and that influence is extending itself in every direction.

But still benevolence is sadly deficient in many, and until the moral feelings shall receive better training, we need hope but for small improvement. Let the theologian fume and fret as he may, however, man is rather good, just, and benevolent, than the reverse. Our present purpose is to show the superiority of this sentiment over all coercive measures in the education of children, in the treatment of the insane, and in the treatment of criminals.

Upon the education of children, in a great measure, depends the future peace and well-being of the community. Until Phrenology pointed out the superiority of goodness and benevolence over all coercion, what was the usual means adopted by teachers to secure the improvement of their pupils? The savage law of corporal punishment on the one hand, or appeals to the self-esteem and vanity of the pupils on the other. In everything else they were completely in the dark; at sea without rudder, chart, or compass, working entirely upon these hap-hazard principles, and accompanying their ignorance of human nature with a pompous magisterial superiority, which terrified rather than conciliated the child. Nor was the conduct of many parents a whit better. When we were engaged in teaching, we recollect a mother coming to us:—"My child makes very slow progress, sir." "He is rather dull and slow, ma'am," said we. "Whip it into him, then," said the amiable parent: "don't you know that to spare the rod is to spoil the child?"

Let us see what this whipping system is capable of accomplishing. At a common school convention in Hampden county, U. S., a clerical speaker related the following anecdote:—"Many years ago, a man went into a district to keep school, and before he had been there a week, many persons came to see him, and kindly told him, that there was one boy in the school whom it would be necessary to whip every day—leading him to infer that such was the custom of the school, and that the inference of injustice towards the boy would be drawn whenever he should escape, *not* when he should suffer. The teacher, however, saw the matter in a different light. He treated the boy with signal kindness and attention. At first this novel course seemed to bewilder him. He could not divine its meaning; but when the persevering kindness of the teacher begat a kindred sentiment in the pupil, his very nature

* Gall's Works, vol. v., p. 156.

seemed transformed. Old impulses died, and a new creation of motives supplied their place. Never was there a more diligent and successful pupil. Now," continued the reverend gentleman, in concluding his narrative, "that boy is the chief justice of a neighbouring state." The relator of the anecdote, though he modestly kept back the fact, was himself the actor.

We pass now to the superiority of benevolence in the treatment of the insane. Although the Faculty seem, as to the majority of its professors, determined to do all in their power to strangle Phrenology—although many of them are as violent, as abusive, and as dogmatical now, as were their predecessors when Harvey discovered and propagated the true doctrine of the circulation of the blood, yet there are professors, and able professors, too, of the healing art, who adopt and apply its principles to the great benefit of their patients. Among these may be mentioned Dr. Sir William Ellis, late physician to the Hanwell Lunatic Asylum, Middlesex. This asylum was formerly conducted on the old principle of violence, chains, whips, strait waistcoats, *et hoc genus omne*. Dr. Ellis, with his truly heroic and good wife, removed all this fiendish apparatus, and determined to govern only by benevolence, or not to rule at all. The result has changed the entire treatment of lunatic patients in this country.

In vol. i., p. 231, of Miss Martineau's Miscellanies, is the following narrative:—

"I have lately been backwards and forwards to the Hanwell Asylum for the reception of the pauper lunatics of the county of Middlesex. On entering the gate, I met a patient going to his garden work with his tools in his hands, and passed three others breaking clods with their forks, and keeping near each other for the sake of being sociable. Further on were three women rolling the grass in company, one of whom, a merry creature, who clapped her hands at the sight of visitors, had been chained to her bed for seven years before she was brought here, but is likely to give little further trouble henceforth than that of finding her enough to do. Further on is another, in a quieter state of content, always calling to mind the strawberries and cream Mrs. Ellis set before the inmates on the lawn last year, and persuading herself that the strawberries could not grow, nor the garden get on, without her, and fiddle-faddling in the sunshine, to her own satisfaction and that of her guardians. This woman had been in a strait waistcoat for ten years before she had been sent to Hanwell.

"There is another place where the greater number of them go with the greatest alacrity to the chapel; where they may be seen on a Sunday evening, decked out in what they consider their best, equalling any other congregation whatever in the decorum of their deportment.

"Where are the chains, the straw, and the darkness? Where are the howls and the yells, without which the place cannot be supposed a madhouse? There is not a chain in the house, nor any intention that there shall be; and those who might in a moment be provoked to howl and yell, are lying quietly in bed, talking to themselves, as there is no one else present to talk to.

"I saw the worst patients in the establishment, and was far more delighted than surprised to see the effect of companionship on those who might be supposed the most likely to irritate each other. One poor creature in a paroxysm of misery could not be passed by; and while I was speaking to her as she sat, two of the most violent patients in the ward joined me. The one wiped away the scalding tears of the sufferer, while the other told me how genteel an education she had received, and how it grieved them all to see her there."

And all this has been brought about by the enlightening power and influence of phrenology, which has gone to the origin of mania, and applied the proper means of remedy; taught the classification of the patients; shown the utility of constant employment, and, above all, the humanizing and softening power of benevolence.

And now we pass to the last division of our subject—benevolence in the treatment of criminals—and again the phrenologist will be found to occupy the vantage ground. Phrenologists have, from the first, contended that education alone can improve the organization; and they have given the most incontrovertible evidence, that where the education has been attended to, even in cases where the organization has been defective and inferior, the organization has been gradually improved, and the happiest results have in the sequel ensued.

But in the case of children whose parents have been criminal, the grossest ignorance is known to prevail. A criminal man has intercourse with an equally criminal woman, and offspring of course follows. The hereditary bias of the parents is communicated to the child, and the education he receives is in strict accordance with the lives of his parents. And so he grows up to manhood; has similar intercourse with similar results, and this child's organization is still worse. Time wheels on; the child becomes a man, and perpetuates his propensities in his offspring. All the schooling the child obtains is in the art of pillage. The brain has gradually receded to its base, and the propensities are the ruling power; the sentiments weak and feeble; the intellect, such as it is, only trained to give the propensities its greatest aid. He is little better than an animal. The business of his life is to thieve; he knows no other trade. (See this further illustrated in the letter of Jack Wild, and in the article Acquisitiveness.)

To prevent the criminal from offending again; to use the punishment as an example to others; to use all practicable means of reforming the criminal, and prevent his again mingling with society till such reformation is accomplished, is surely the duty of the legislator.

Punishment is itself an evil; it is indeed the result of a violation of some law of order, and every such violation brings with it, in a greater or less degree, its own penalty. "Now all inflicted evil," says Jeremy Bentham, "which does not dispose the delinquent (and by his example other men) to obey the laws, is not punishment, but an act of hostility. Besides, public feeling generally errs on the maximum side of punishment, and therefore the legislator should take care to keep his punishments on the merciful side of popular opinion. Now, let us test the punishment of death by these considerations: and *first*, does capital punishment prevent the criminal from offending again? Undoubtedly it does, and in the most effectual way, too, for the life of the criminal being sacrificed, he cannot err again. But does the legislator, in inflicting death, observe his principle of economy in punishment? He certainly does not; nay, he most glaringly outrages it. Imprisonment would effect what execution cannot. Why do we imprison the insane? Because we desire to prevent them from doing injury. But far more injury is likely to result from the unbridled passion of a madman, than from a criminal, however desperate. If the imprisonment of the one secures us from dread, why should not the imprisonment of the other? But, *secondly*, the duty of the legislator is to adopt such a punishment as will operate as a warning, and tend to prevent crime in others. Does capital punishment effect this? Alas, no! We find, by melancholy experience, that the more capital punishment is employed, the more frequently capital crimes are committed; and when an execution for murder takes place, it seems to be the precursor of new murders, and with frequently some new or startling features of atrocity in the crime. We have read, and all have read, of murders committed in defiance of restraining power, that is, of the restraining power of public executions, but never have we read that a public execution operated as a check upon those who witnessed it. In 1846 (March 14) a man lay under sentence of death in Newgate, and that man had, previous to his incarceration, witnessed the three last executions at the Old Bailey. Indeed, it has actually happened that the witnessing of an execution has operated as a stimulus to the perpetration of the crime of murder. A carpenter who had witnessed, previous to going to his day's labour, an execution on the Continent, and who, after the law had been satisfied, proceeded to his workshop with his basket of tools over his shoulder, came unexpectedly upon the heels of another workman, when the horrid thought struck him, how nicely he could cut the man's head off with his axe, and in a moment the axe was withdrawn from the tool basket, and the poor victim lay a corpse at the foot of the horror-struck murderer, who instantly delivered himself up to the authorities, but could give no other account of the reason for committing the crime, than the im-

pression which previous witnessing of the execution had made upon him. He was also condemned to be beheaded. We think, then, it may be fairly inferred, that though an execution may stimulate to the commission of a murder, it will never be the means of preventing one. Are death punishments, then, likely to prevent murder? We think not. Tawell stated that the idea of murdering his victim took such complete possession of his soul that he was utterly insensible to consequences. Connor, an Old Bailey victim, witnessed an execution on the morning of the very day when he committed the murder for which he suffered. Thus we see that the sight of the very gallows itself, with its struggling victim, made no impression on Connor, and Tawell declared he was utterly insensible to consequences. Lord Bacon has remarked—'It is worthy the observing, that there is no passion in the mind of man so weak but it mates and masters the fear of death: and therefore, *death* is no such terrible enemy. Revenge triumphs over death; love slights it; fear preoccupieth it; out of pity many seek it; nay, niceness and satiety lead men to desire it.'" Most certainly this is the truth. How many seek the bubble reputation even in the cannon's mouth; and a shilling a day, red coats, and army rations, have attracted some of the handsomest men this and other countries have produced! No: death punishments are not likely to prevent the crime of murder. A man named Campbell, sentenced to death at Glasgow in 1831, thus addressed the judge: "Thank you, my lord! Death is sweeter than confinement: cowards die many times, I will die but once." What now must we think of the fear of death with these examples before us? And yet this is the fear to which our legislators appeal. One other consideration remains to be noticed before we leave this part of our subject:—Is capital punishment reformatory? We will answer this question by a quotation from the work of Mr. Rowton:—"We are told," says he, "that in the interval between the sentence and the execution, the criminal finds leisure to open his eyes to the eternity that lies before him." Leisure!!! Are the few hours allowed by the law to be described as the hopeful leisure-time, in which the wretched being, thrice dyed in guilt, perhaps is for the first time to learn his path to the world to come? Hurled into the abyss of terror, is he then to find sure footing? With remorse, anguish, shame, stupefaction, horror, and dread, all crowding into his miserable soul at once, are his moments leisure moments, think you? Oh no! no! they are mad moments, as many a thrilling page in the Newgate Calendar testifies (and as the case of the girl recently executed at Bristol confirms). A few hours to repent of a lifetime's sin! What mind can calmly contemplate the fearful alternative? What mind but must be unstrung and maddened by the thought? God has fixed man's death hour, but He has not revealed it to him, because the dread of it would overwhelm him. Why should we presume that God is wrong by asserting, as we do, that to reveal the hour is more fully to awaken the soul to a sense of its vast importance. Dying signs are not always to be depended upon. While Tawell was praying and reading the scriptures from morning till night, and exhibiting the most promising signs of real devotion and inward peace, he was still denying, not by word but by act, that he had done the deed for which he was condemned. We have brought it then to this: that not only does capital punishment prevent social reformation, and remove a labourer from the community, who might (not free, of course, but in imprisonment or restraint) be made of service, and have real leisure to repent, but that it maddens the soul of the criminal, prevents his penitence, and so, by despatching an unprepared soul to God's judgment-seat, makes the punishment an everlasting one, and destroys both soul and body in hell.

But now we approach a more important part of our subject—namely, has Government any right to inflict the punishment of death? There is a good deal said at the present day about expedience; but those who are constantly using the word, seldom inquire into the *right*, which he, by his views of expedience, enforces a law. Thus, to the legislator, the crime of murder is of the deepest dye—unquestionably it is; and it is expedient it should be punished by the severest punishment—granted again; but has man a right to commit a murder in retaliation for a murder? We say he has not. We certainly, to use a high authority, do not live for ourselves. None of us liveth unto himself, and none of us dieth unto himself. Why do we hold inquisition over the remains of a man who has committed self-destruction? Because we view life as a sacred trust committed to his charge by his Creator; and so viewing it, we conceive that man has no right over his own life, and consequently no right to abridge it, or deprive society of the use which his individual assistance can give to the public good. We are all enlisted under the banners of a great Captain, to do battle against evil and falsehood; and while a breath of life remains in us, we must do battle against these evil and false principles. Suicide is a grievous evil, and men brand it as such, and juries bring in their verdicts of *felo de se*, that it may be so considered. But if we have no right over our own lives, what right have we over the lives of others? And if this be so, who shall say that a Government has any right to inflict the extreme punishment of death? In the House of Lords, September 6th, 1831, one of the ablest lawyers this country has produced (Lord Brougham) made the following remarks:—"We have no right to shed a criminal's blood, because he has shed the blood of another man. We have no right in reason to do this; we have no warrant from religion. It is, doubtless, a great evil for a man to be murdered; but that, in reason, is no argument for inflicting death upon the murderer."

It usually happens that those questions which are of the greatest importance to the welfare of mankind, are the last to become the subjects of general public discussion. The practical details of life form the objects to which the action of popular opinion is more immediately directed, and it is only when the evil-working of any of these details is shown to be beyond the possibility of reform, unless by an attack on some great principle to which they owe their origin, that men can be persuaded to question the soundness of any general idea, upon which, through past time, they may have been accustomed to rely. Hitherto we have been accustomed to look upon criminals as persons whom to get rid of, as speedily as possible, would be our soundest policy, and our criminal code has, in consequence, been one of vengeance instead of reformation. A series of years has so deteriorated the organization, that power to reason has nearly been lost, and the gratification of the propensities has been the chief object of the criminal.

There are very few persons, indeed, whose criminal actions have brought them to the scaffold, but have given warning, in earlier years or at previous periods, of their dangerous dispositions and propensities. But society seems not to have acted upon these premonitions. In June, 1840, the following case appeared in the Glasgow newspapers:—"A man, named Miller, a barber, at the Broomielaw, was arraigned before Bailie Small on the charge of fearfully maltreating his wife. The evidence which was adduced brought out a case of extreme barbarity. It appeared that the man had thrown her down stairs—kicked her, dashed her into the fire, and inflicted many other cruel injuries. The man had a curious method of refinement with his cruelty; for it was brought out in evidence, that he was used to place a razor and huge ham-knife under his wife's pillow, upon which he forced her to lie down, hinting, at the same time, that he would operate upon her with them as soon as he found it convenient. Bailie Small sentenced him to confinement in Bridewell for sixty days, and almost regretted that the case had not been taken before a higher tribunal, as this was not, by any means, the first instance of his cruelty." Now, here was a warning of the most serious kind given to society, and the magistrate takes advantage of it by giving the man sixty days' confinement in Bridewell—all, it is true, that the law allows him to inflict. After he is released, as is most probable, he will be more exasperated, his passions more inflamed, and if he should commit a murder, why, then the law will lay hold of him, and commit another in return; whereas, had proper means of prevention been adopted, he might have been so improved as to have been permitted to mingle with his fellows without danger either to himself or them. The fact is, that punishments are very arbitrarily and inefficiently inflicted, and, in very many instances, crimes which should call for long imprisonment, and strict reformatory dis-

cipline, are, like the case just mentioned, most summarily disposed of—not that the criminal might sin no more, but, as it might appear, that he should sin more deeply. Now, while we contend for the abolition of capital punishment, we at the same time contend that punishment should be certain, and founded on that restraint which should prevent the criminal from indulging in his favourite delinquencies. In Macnish's 'Anatomy of Drunkenness,' the following characteristic anecdote is related:—"A gentleman of very amiable disposition, and justly popular, contracted habits of intemperance. His friends argued, implored, remonstrated. At last he put an end to all importunity in this manner, to a friend who was addressing him in the following strain—'Dear Sir George, your family are in the utmost distress on account of this unfortunate habit. They perceive that business is neglected, your moral influence is gone, your health is ruined, and depend upon it the coats of your stomach will soon give way, and then a change will come too late.' The poor victim, deeply convinced of the hopelessness of his case, replied thus: 'My good friend, your remarks are just; they are indeed too true; but I can no longer resist the temptation. If a bottle of brandy stood at one hand, and the pit of hell yawned at the other, and I were sure I should be pushed in, as sure as I took one glass, I could not refrain. You are very kind. I ought to be thankful for so many kind and good friends. But you may spare yourselves the trouble of trying to reform me; the thing is impossible.'"

To this man, who confessed that even the certainty of eternal torture would have no effect in deterring him from the gratification of his propensity, what terror would have been imparted by any human punishment?

Now, to our view, this man was a lunatic, and true love, on the part of his relations, ought to have led to his treatment as a lunatic. Confinement and restraint could alone have effected his cure.

Our space will not allow us to enter any further into this matter; we will, therefore, conclude with one anecdote of the power of kindness in criminal treatment. It is from Miss Martineau's 'Retrospect of Western Travel:'—

"The wonderfully successful friend of criminals, Captain Pillsbury, of the Weatherfield prison, owes his success entirely to his benevolence. His moral power over the guilty is so remarkable, that prison-breakers, who can be confined nowhere else, are sent to him to be charmed into staying their term out. I was told of his treatment of two such. One was a gigantic personage, the terror of the country, who had plunged deeper and deeper into crime for seventeen years. Captain Pillsbury told him when he came, that he hoped he would not repeat the attempts to escape which he had made elsewhere. 'It will be best,' said he, 'that you and I should treat each other as well as we can. I will make you as comfortable as I possibly can, and shall be anxious to be your friend, and I hope you will not get me into any difficulty on your account. There is a cell intended for solitary confinement, but we have never used it, and I should be sorry even to turn the key upon anybody. You may range the place as freely as I do, if you will trust me as fully as I shall trust you.' The man was sulky, and for weeks showed only gradual symptoms of softening, under the operation of Captain Pillsbury's cheerful confidence. At length information was given to the captain of the man's intention to break prison. The captain called him, and taxed him with it: the man preserved a gloomy silence. He was told that it was now necessary for him to be locked up in the solitary cell, and desired to follow; the captain, who went first, carrying a lamp in one hand, and a key in the other. In the narrowest part of the passage, the captain, who is a small slight man, turned round, and looked in the face of the stout criminal. 'Now,' said he, 'I ask you if you have treated me as I deserve? I have done everything I could think of to make you comfortable. I have trusted you, and yet you have never given me the least mark of confidence in return, and have even planned to get me into difficulty. Is this kind? And yet I cannot bear to lock you up, if I had the least sign that you cared for me.'

"The man burst into tears. 'Sir,' said he, 'I have been a very devil these seventeen years, but you treat me like a man.'

"'Come, let us go back,' said the captain. The convict had the free range of the prison as before. From that hour he began to open his heart to the captain, and cheerfully fulfilled the whole term of imprisonment, confiding to his friend, as they arose, all impulses to violate his trust, and facilities for doing so, which he imagined he saw.

"Captain Pillsbury is the gentleman who, on being told that a desperate prisoner had sworn to murder him, speedily sent for him to shave him, allowing no one to be present. He eyed the man, pointed to the razor, and desired him to shave him. The prisoner's hand trembled, but he went through it very well. When he had done, the captain said, 'I have been told you meant to murder me, but I thought I might trust you. 'God bless you, sir, you may,' replied the man."

Such is the power of benevolence over the most desperate profligacy and ferocity.

SKETCH OF THE METAL MANUFACTURES.

CHAPTER III.

STEEL AND CUTLERY—FILES, SAWS, &C.

We have spoken of Sheffield as the steel-making metropolis; but it must be viewed a little more closely. We must regard it as one great workshop for the production of cutlery and edge tools—a huge factory, which scatters its separate departments in different parts of the town, but still retains them all, like so many links in a chain.

If we take a directory of Sheffield as an index to the employments of its inhabitants, we shall see that, although the distinct occupations are very numerous, there is yet a tie which connects most of them together: cutting instruments, of some kind or other, being the objects to which most of the manufacturing arrangements relate. There are cutlery casters, table-knife makers, fork-makers, penknife-makers, lancet-makers, razor-makers, scythe-makers, saw-makers, edge-tool makers, scissor-makers, shear-makers, spade and shovel makers: preparatory to all these are the operations of the steel converters, and tilters, and rollers, and casters; subsidiary to them are those connected with the making of handles, such as ivory, tortoiseshell, and pearl dealers, ivory-cutters, horn merchants and dealers, horn-pressers, bone merchants and dealers, bone-pressers; and lastly, there are numberless minor occupations which contribute in various ways to the manufacture of cutlery, such as casting-pot makers, mark and figure-makers, razor-strop makers, studders and handle-ornamenters, and many others. It is true that other manufactures are carried on to a considerable extent; for instance, the immense supply of steel at hand affords facilities for the production of various articles, such as fenders, wire, anvils, hammers; the large use of horn for handles has led to the settlement of the comb manufacture at Sheffield; the supply of bone for handles has given rise to button-mould making; and there are considerable manufactures in white metal, including silver and its various imitations. But still all these are so far outweighed by the arrangements connected with cutlery, that the latter must be deemed the staple, the characteristic, the distinguishing feature of Sheffield industry.

Like as in other instances, Sheffield has grown up to its present distinction by gradual advances. At the time when archery supplied the use of fire-arms throughout England, Sheffield is stated to have been celebrated for the manufacture of iron heads for arrows: and it was known by Chaucer as a place where blades of knives were made; for a character in one of his poems is mentioned as being furnished with a '*Sheffield thwytel*' (whittle), a kind of knife which used in those days to be carried about the person. Rather more than two centuries ago the principal cutlers formed themselves into a body corporate, for the protection of the trade, and especially for the protection of the 'marks' belonging to each individual,

with a view to guard against the piracy of these marks by persons to whom they do not belong. It was about a century ago that the cutlery of Sheffield began to acquire such decided excellence as to raise it to a high rank. But it was not until the introduction of the mode of making cast-steel that this reputation reached its height; and at the present day it is not merely in the making of the steel, but also in the mechanical details of the manufacture, that the quality of the Sheffield steel goods is shown and appreciated.

Perhaps the mode in which we may best glance at the cutlery manufacture is to take, one by one, a few cutting instruments as examples, and see what are the chief processes which they undergo.

TABLE-KNIVES.

A table-knife is perhaps the most important of the different articles of cutlery—not from its quality, for a razor is more highly finished; not from its intricacy, for a clasp-knife has more detail about it—but from the large extent to which the use has risen. Every house in England, except the very humblest, has as many table-knives in it as there are inmates; and most houses have a great many more. When we consider, too, that table-knives, as well as other articles, have the art of wearing away, and that the industry and the brickdust of the housemaid greatly hasten this process; and when we look abroad to notice the avidity which all rude nations exhibit to gain possession of an English knife—we shall be prepared to regard this as a very extensive branch of Sheffield manufacture.

There is in most of the operations on steel goods a series of processes pretty constant in their general character. The forging, the hardening, the tempering, the grinding, the sharpening, the polishing—all form steps in most of the series, and bear a certain resemblance in their general character. A table-knife, for instance, is forged out of a piece of steel of higher or lower quality, according to the price at which it is to be sold. The very commonest are probably not steel at all, being simply bar-iron; the next quality may be common steel, the next shear-steel, and the highest of all cast-steel. But whatever be the material, a length of bar is cut off, sufficient for one blade, and forged into shape. All the Sheffield forges are pretty much alike. They consist of a forge-fire kindled by bellows; and have a large block of stone or wood, serving as a bench, and provided with small steel anvils, stithys, bosses, hammers, and other instruments necessary to the operation. The piece of steel is heated in the fire, placed on an anvil and hammered into form; being turned over and about in every direction, and the workman regulating his blows according to the form which he wishes to produce, reducing the thickness from one end to the other, and from one edge to the other. But this relates to the blade only; the 'tang,' or part which goes into the handle, is a separate part. To make this tang, the rudely-formed blade is welded to a rod of iron, about half an inch square; and a sufficient length of this iron is cut off to form the tang, and also the 'shoulder,' or the projecting part between the tang and the blade. The end of the iron is heated and forged, so as to be reduced in size sufficient to form the tang; and the shoulder is next brought into shape by hammering it in a kind of die or stamp, called a 'swage.' The tang and the bolster being made, the whole is heated a second time, and the proper form and dimensions given to it. The blade is then heated red-hot, and plunged perpendicularly into cold water, by which a sudden hardening is effected; and a gradual heating afterwards to a certain point gives the 'temper' or degree of elasticity best fitted for the purpose to which table-knives are to be applied.

When the knives are thus far prepared, they are carried to the grinding-wheels, where the blade is ground all over on a large revolving stone; whereby the surface is brought level, the edges made straight, or at least regular, the point rounded or tapered as the case may be, and the edge sharpened. The grindstones made use of for grinding table-knives are between three and four feet in diameter, and about six inches broad upon the face. They are formed of a species of sandstone, and revolve with great rapidity, without at the same time greatly heating the articles being ground. The knives are ground first upon this stone, and afterwards upon one of finer texture, called the 'whitening-stone.'

Here it may be well to notice the customary arrangements at Sheffield respecting the grinding of steel goods. As the town is dotted here and there with '*Tilts*,' so is it likewise with '*Wheels*;' and in the one case as well as in the other, the name is an abbreviation well known among the townsmen. A 'wheel' is a building fitted up with a large number of grindstones, each hired at a weekly or yearly rental by a grinder, who grinds some kinds or other of cutlery for other persons. Before the introduction of steam-power, the grinding-wheels were in most cases situated by the side of a fall in one or other of the rivers of Sheffield, so as to obtain the action of a water-wheel; and these little structures often presented a picturesque appearance. But in modern times large buildings have been appropriated for this purpose, amply provided with steam-power. There is one building in particular, called the Castle Mills, situated near the junction of the Sheaf and the Don, which is especially calculated to illustrate this arrangement. It is a large castellated structure—open to the objection, perhaps, of exhibiting a style of architecture wholly inconsistent with the nature of the mechanical operation going on within. There is a central court-yard surrounded by buildings, and at different heights are galleries running round, with doors opening into numerous apartments on all sides. The south side of the building is adjacent to the river Don; but a steam-engine supplies the moving power. If we go into the rooms of this building, we find men employed in grinding all the various kinds of Sheffield steel goods. The men in one room are grinding saws, in another table-knives, in another pen and pocket knives, in another forks, in another scissors, in another razors; employing grindstones of all sizes, from four inches to seven feet in diameter, and of varying quality.

All are brought into connection with the moving power by means of the usual mechanism; and it is on these revolving stones that the grinding is effected.

In such places as this Castle Mill, every man confines himself pretty nearly to one kind of work, and pays a rental to the proprietor for the use of the room and the steam-power; or sometimes a man hires a whole room containing several grindstones, and either employs others to work for him, or sublets some of the room. When walking round the gallery, and looking in one room after another, we may see the men in their cramped attitudes (for it is never an easy one) bending over the grindstones, and engaged from morning till night in grinding articles of cutlery or other steel goods. These goods are not their own, but belong to others, who merely employ them as grinders.

But to return to our table-knives. When the knives are ground, they are ready for 'glazing' or 'polishing.' This is performed on a wheel called a 'glazer;' consisting of a circular piece of wood, fixed upon an iron axis, and coated on the edge either with leather or with a ring of metal, consisting of an alloy of lead and tin. The leather-faced glazers, used for glazing table-knives, are first covered with a solution of glue, and then with emery powder; and it is by friction against this slightly roughened substance that the glazing of the knife-blade and shoulder is effected. The extent to which this process is carried on, has led to the establishment of 'buff and glazer makers' among the trades of Sheffield.

FORKS.

Fork-making is not without its peculiarities among the departments of Sheffield industry. Most of the fork-makers live in the environs of the town; and indeed there are one or two villages almost wholly inhabited by these operatives. Forks are in most cases made of 'common steel,' that is, blister steel which has been drawn out under the hammer, but neither sheared nor cast. They are forged out of rods about three-eighths of an inch square, in the following manner:—The tang and shank of the fork are first roughly formed, by hammering out the metal while in a red-hot state; and, being again heated, the proper contour is given to them by means of a die and swage or stamp. The prongs are formed by stamp-

ing with a powerful punch, acting on the principle of the pile-driving machine, but of course with a force proportionate to the work to be done. There is a large anvil fixed in a block of stone nearly on a level with the ground; to this are attached two rods of iron of considerable thickness, fixed about a foot asunder, perpendicular to the anvil, and reaching to the ceiling; the hammer or stamp, weighing about a hundred pounds, grooved on each side, slides up and down by means of the iron rods, which act as guides; a rope, passing from the hammer over a pulley, gives the workman the means of raising the hammer; and, lastly, the lower surface of the hammer and the upper surface of the anvil are each provided with a die or stamp adapted to the cutting of the prongs. The blank fork, being heated to a certain degree of softness, is placed on the lower die, and the hammer containing the other die is made to fall upon it from a height of six or seven feet. This forms the prongs and the middle part of the fork, leaving a very thin substance of steel between the prongs, which is afterwards cut out by means of a fly-press. The forks thus brought to the form so familiar to us, are annealed by heating in an oven and then gradually cooling, so as to acquire a softness sufficient to enable them to be filed all round and between the prongs. After this they are hardened, by being heated and suddenly cooled.

The grinding of forks is one of the most lamentable operations in the whole series of manufacturing processes, from its deleterious effects on the health. Forks are ground upon a dry stone, called the "fork-stone," formed of sharp grit of a whitish colour, very similar to that of which millstones are formed. The stone is about half a yard in diameter, and two inches broad at the edge. The grinder sits on a "horse" or stool, bends over the stone, holds the fork crosswise against the stone, and grinds all the parts of the surface to a smooth and even condition. If the stone were wetted, as in most other cases, the inconvenience would not be great; but the stone is kept quite dry, whereby not only is there a profusion of sparks given out, but the face and head of the grinder are enveloped in an atmosphere loaded with small particles of steel and gritstone, which are inhaled into the lungs. Such is likewise the case in the process of needle-grinding; and in both instances the workmen infallibly fall victims to a distressing disease known as the "grinder's asthma." It is said that there are hardly any fork-grinders more than forty years of age, since the disease carries off most of them before they reach that time of life. Mr. Abraham, of Sheffield, some years ago devised a remedy for this sad evil, by placing a shield of magnets in front of the grinder's mouth, whereby the small particles should be arrested and prevented from entering the lungs. Another plan has been suggested by a Mr. Elliot; which consists in the adoption of a long box or wooden chimney, placed opposite to and partially covering the grindstone in front, while the other extremity is carried through a hole in the wall; in this arrangement it is said that such a current of air is excited by the mere revolution of the stone, as to carry the dusty particles through this funnel into the open air outside the building. Yet both these plans have been rejected by the workmen, and so have all others having for their object the amelioration of this employment. Whether it is that the contrivances are very troublesome to arrange, or whether the grinders wish the occupation to remain unhealthy in order that wages may remain high (and both opinions have been expressed), certain it is that dry grinding is still what it has ever been—one of the most disastrous occupations connected with the manufacturing arts; and it is equally certain, that unless the men aid the attempts made for their comfort, all such attempts must be fruitless.

PEN AND POCKET KNIVES.

A table-knife maker does not and probably cannot make a clasp-knife. He uses tools of different size, and his hand and his eye become accustomed to a kind of work from which he could not readily depart.

Penknives are generally forged by one man, with the hammer and anvil simply, the former weighing between three and four pounds, with a face or surface about an inch in diameter. The blade of the knife is first hammered out at the end of the rod of steel, and as much more is cut off along with it as is thought necessary to form the joint. The blade is then taken in a pair of tongs, and heated a second time to finish the joint part, a temporary tang or prong being formed at the same time. The blade is again heated, and hammered to a better and more correct form; and while yet hot, it is cut or stamped with a crescent-shaped chisel to form the nail-hole or notch by which clasp-knives are always opened. The blade is hardened by being brought to a red heat, and then dipped in cold water up to the shoulder.

The blades of pocket-knives, and of all other kinds of clasp-knives, are made nearly in the same way; and at a certain stage in the proceedings they are sent to a "wheel" to be ground; after which they are "glazed" on a leaden wheel coated with emery; and the finer kinds are still further polished on a circular piece of wood covered with buff leather, and coated with a paste or composition.

The finishing of a penknife is a curious instance of minute detail. When the pieces of ivory, pearl, tortoise-sheel, horn, or bone, which are to form the outer surface of the handle, are roughly cut to shape; when the blade has been forged and ground; and when the steel for the spring is procured—the whole are placed in the hands of a workman who proceeds to build up a clasp-knife from the little fragments placed at his disposal. So many are the little matters which he has to attend to, that a common two-bladed knife has to pass through his hands seventy or eighty times before it is finished.

When we speak of an "ivory-handled," or "pearl-handled" penknife, the ivory or pearl is said by the workman to form the "outer-scale" of the knife, and is only for ornament; the real foundation of the handle being the "inner-scale," which is formed of metal. The spring is the piece of steel, which, running along the back edge of the knife, separates the two scales or halves of the handle; and by its elasticity exerted upon the tang of the blade, it secures the blade in certain positions—closed, half-closed, or open. The inner scales and the spring are both forged to the workman's hands, and his office consists in putting all the pieces together. He works at a small bench near a window, and is provided with a number of tools to facilitate his operations—such as a vice, a small anvil, hammers, several files, steel burnishers, a drill-bow, and drills for boring holes, a glazer coated with emery, a polisher coated with oil and rottenstone, steel-plates to act as gauges in making holes through the various parts of the knife, and a number of other little appliances which we cannot enumerate. With the aid of these he shapes and adjusts his various pieces, fastens them with pins or rivets, files down these pins to give them a neat and level appearance, polishes every part after it is fixed; and, in short, he does to a penknife what a watchmaker does to a watch—he makes very few of the parts, but he adjusts them all.

RAZORS.

Here we come to a species of cutlery which has perhaps excited more attention than any other; respecting which more has been written, and in the preparation of which more care is taken. Commercially speaking, this department of manufacture is not so important as that of table-knives, from its much more limited application; but the good quality requisite to the fit action of a razor, has made it an object of moment both to the steel-maker and the cutler.

The blade of a razor is forged much in the same manner as the blade of a knife, but from steel of a particular quality. The rod of steel is heated at one end, and hammered into a shape bearing a rude resemblance to that of a razor. The concavity of the surface is produced by hammering the blade on the rounded edge of the anvil. The piece is then cut off, with an additional length sufficient to form the tang for insertion in the handle. The quality of the metal is required to be peculiar on this account, that the thickness of the back and the edge of a razor differ so greatly, that much hammering is necessary to produce the latter, and the hammering can only be borne by good metal. Some razors are made with a straight edge, some with a convex edge, some of equal breadth throughout, some wider at the point than near the handle, some short and broad, some long

and narrow; but these are all differences to suit individual taste, and have little to do with the real quality of the razor.

Razors are generally tempered before they are ground; but sometimes ground before they are tempered. They are ground upon very small stones, often those which have been worn away to too small a size for other grinders. The reader may perhaps have seen or heard of razors "ground upon a 4-inch stone;" this character being mentioned as a test of excellence. What is here meant may be explained as follows:—Every razor is concave or hollow on the surface; this concavity must be produced or maintained in grinding by the use of a stone equally convex. When a stone four inches in diameter is employed, it must give to the razor a corresponding concavity, or a curve of two inches radius; and it is evident that this can only be produced by wearing away the substance of the razor in such a way as to give a very thin edge. Now the thinner the edge, the finer and sharper can it be made in the process of "whetting;" and hence there is an inference that, other things being equal, a razor "ground upon a 4-inch stone" will yield a keener edge than one ground on a stone six, eight, or ten inches in diameter. On the other hand, any man who is blessed with a strong wiry beard, will find that a very fine and delicate edge is spoiled almost immediately by it; he must have a razor whose edge possesses strength as well as keenness, and such a one must have been ground on a stone larger than four inches in diameter. Taking all these points together, therefore, it seems probable that the concavity of a razor ought to bear some relation to the kind of beard with which it is to be brought in contact; and that a medium concavity, produced by grinding the razor on a stone six or seven inches in diameter, is more likely to be generally serviceable than any other. If the reader knew how many "Essays on Razors" have been written, and how earnestly all these points are discussed, he would see that they are not deemed so trifling as might at first appear.

The tempering of a razor is not less important than the grinding, since the fineness and durability of the edge depend greatly on it. This tempering is given by exposing the article to a certain temperature, and then allowing it to cool gradually, the particular temperature chosen being a matter of experience. No one seems yet to know why a particular temperature gives a particular temper; there is no known general principle which pervades all the applications; and therefore each cutler or workman uses such a heat, and tests it by such signs, as seem best to accord with the result of his own experience. In general, the *colour* which the steel attains while hot is taken as the test, each kind of cutlery having a colour best fitted for itself. Others endeavour to use a thermometer to direct their proceedings; and we give the following table to show how the two have sometimes been worked out together:—

Fahr.	Colour.	
430°	Slight yellow	Fitted for razors and lancets.
450	Pale straw	
470	Yellow	Penknives.
490	Brown	
510	Brown, with purple spots	Pocket-knives, table-knives, scissors.
530	Bright blue	
550	Purple	
560	Blue	Springs.
600	Blackish blue	

We can only give this as one instance of an attempt at system; for almost every distinguished cutler has favourite views of his own respecting the tempering of cutting instruments.

The razor, when ground, tempered, and polished, is fitted into its handle by means similar in character to those employed in handling penknives, but less complex.

It may be remarked, that among the points yet undetermined concerning the quality of razors, the condition of the iron whence the steel is made has not yet been fully understood. It has been supposed by some that steel, or the iron from which it is made, is improved in quality by being buried in the earth for a long time. A curious instance occurred a few years ago in illustration of this opinion. An eminent London cutler, having buried some razor-blades for three years in the earth, and having formed an opinion that the quality was greatly improved thereby, was desirous of obtaining some iron or steel which had been so buried for a much longer period. It happened that about that time Old London Bridge was pulled down, and all the piles were found shod or pointed at the lower end with iron, which had been thus immersed in the earth for many centuries. The cutler bought all this iron, fifteen tons in weight, and had it converted into steel. The thicker portions yielded indifferent steel; but the thinner, which were both more sonorous and more tough than any other iron known, produced a kind of steel superior, it is said, to any that the cutler had previously known, so that it was said at the time, "We might mow our beards with a relic of Old London Bridge."

It may be added, that iron is occasionally made of so good a quality, that it is capable of being formed into razors without previous conversion into steel.

SCISSORS.

These implements of cutlery, though appearing to the eye more complex than knives and razors, are produced in a way very similar to them. In forging scissors, each half is of course made separately, by the aid of the forge, the hammer, and the anvil. The anvil of the scissor-forger is rather a large block of steel, having grooves on its surface for admitting various little indented tools, called *bosses*. One of these bosses assists the workman in giving a proper figure to the shank of the scissors, another for forming that part which is to receive the rivet, and a third for giving a proper figure to the upper side of the blade. There are also contrivances to assist in giving shape to the bow or handle of the scissors.

The shank of the scissors is first formed by means of one of the bosses, leaving as much steel at the end as will form the blade; and a small hole is punched, to form the first semblance of the bow or handle. The form of the blade is then given, and the piece cut off from the bar of steel. The small hole is next enlarged, by various implements, to the form and shape of the bow.

When many are thus forged, they are annealed to a state of greater softness, grouped together in pairs, and filed regular in all those parts which the grindstone cannot reach. The rivet-hole is then bored; and after being hardened and again tempered down to a particular point, they are sent to the wheel to be ground. The grindstone employed for small scissors is about the same size as that used for penknives; but the outer surface is ground on a larger stone. After the grinding, the scissors are glazed, and afterwards polished, if they be of the best kind. Since there are parts of the scissors which cannot be reached by the glazing and polishing wheels, a small wheel is employed, having hard brushes on its circumference, the bristles of which penetrate to the intricate parts of the scissors, and polish them by means of emery or crocus.

As scissors are made from a farthing a pair to ten guineas a pair, every possible stage in the process, and every shade of difference in the quality of the material employed, are made to bear a proportion to the price at which the article is sold; but the above sketches forth the general routine. In large scissors the face of the blade only is made of steel, all else being made of iron; in cheap articles, the metal is cast at once into a scissor-mould, so as to save the expense of forging; in the costly kinds the handles are chased or etched, or studded with small ornaments, or inlaid with gold—according to the value placed upon them.

HANDLES.

We have more than once had to speak of the handles for knives, razors, and other articles of cutlery. These form an important and extensive department of Sheffield industry, leading to a vast consumption of material.

According to the technical phraseology applied, all handles are called *hafts*, in which a tang of the knife passes into a hole in the handle, and is there fixed; while the handles which are formed of two flat pieces riveted to a central plate, as in penknives, are called *scales*. A "haft and scale maker," therefore (one of the trades of Sheffield), is in fact a handle-maker.

The workmen who engage in this employment confine them-

selves each pretty nearly to one kind of material. The pearl-handle makers procure the shells from the shores of India and Africa; these shells are about six inches in diameter, and are so extremely hard that they have to be wetted while being cut with a saw, to prevent the saw from being softened by the heat. This is a dirty occupation, and is accompanied by a

"Very ancient and fish-like smell,"

elicited by the heat from the shell itself. The pearl, or rather mother-of-pearl, is cut up into thin slices, to be afterwards used for the scales for penknives, razors, &c. *Ivory* handles are made by sawing up elephants' tusks into the most useful pieces they can make, by means of a circular saw. If the ivory is for scales, it is cut into veneers; but if for hafts, it is cut into small oblong pieces, which are afterwards brought to shape by hand, polished, and pierced for the reception of the tang. *Bone* handles are similarly made by cutting with a small circular saw, and then filing into shape; and the same may be said of *ebony* and fancy-wood handles generally. *Saw-handles* are cut out of wood, which, after being planed to the proper thickness, is fixed in a vice, cut with a very fine saw, smoothed with files and glass-paper, pierced with rivet-holes, and riveted to the saws. *Metal* handles are, of course, made in a way similar to other articles of metal.

Horn handles have a peculiarity in their mode of manufacture, which places them in a distinct rank. When horn is made hot, it becomes so soft and ductile that it may be pressed into moulds; and this circumstance is taken advantage of to give an ornamental device to horn handles, except *stag's horn*, which is left in its natural state. The tips or solid part of ox-horn and buffalo-horn are made into hafts, while the other parts are made into scales. The mould for pressing is in two halves, which close together like a pair of pincers; and this mould has the device on each of its halves. The mould is heated in a fire; the piece of horn is cut nearly to the requisite size, and put into it; and the mould is pressed in a powerful vice, whereby the horn receives the impress of the device.

There is also a good deal of skill shown in staining horn, bone, and ivory, or in bleaching them; as also in studding and ornamenting them in various ways.

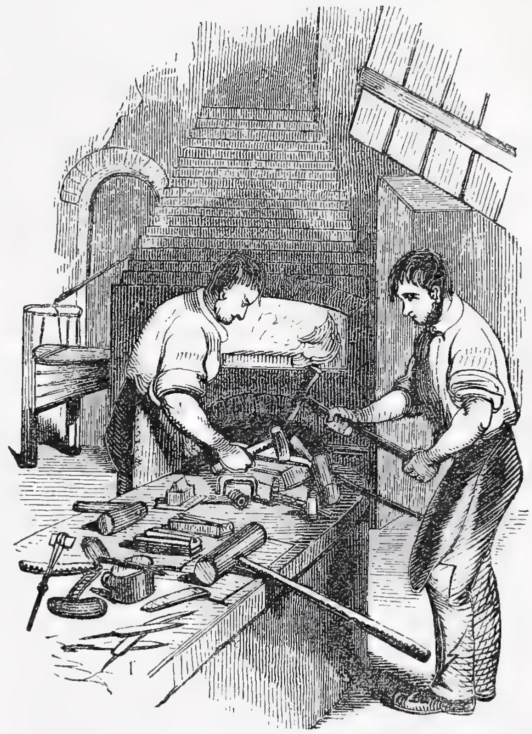
FILES.

These tools, simple and unimportant as they may seem, and probably do seem, to those who never enter an artisan's workshop, are among the most noteworthy articles made of steel. They are the working-tools by which every other kind of working-tool is in some degree fashioned. Whether a man is making a watch or a steam-engine, a knife or a plough, a pin or a coach, he would be brought to a stand if he had not files at his command. It may be a file with a hundred serrations to an inch, or with six or eight; it may have straight cuts like most files, or angular indentations like a rasp; it may be two inches long, or a yard long; it may be round, or half-round, or triangular, or square, or flat; blunt or pointed, straight or curved; but a file of some sort or other will be found in almost every workshop.

The first place to which we have to follow the file-makers is the *forge*. There is on one side a forge-fire, with a hearth on which to place the fuel, and bellows placed behind, much in the same way as a common smith's forge, but with more attention to neatness and order. The workman's bench, if we may use such a term, is a large block of hard stone, weighing perhaps three or four tons, and placed firmly on the earthen floor of the smithy or forge. On this are fixed one or more steel anvils, adapted by their size and shape to support the pieces of bar-steel while being forged into the form of files. There are also hammers of various sizes and peculiar shapes, and other small implements necessary to the operation. A file ought to be made of the very best steel, and is so, unless—like the razors mentioned by Peter Pindar, or the gross of green spectacles immortalized in the "Vicar of Wakefield"—they are merely "made to sell." If a file be too soft, the whole toothed surface would be crushed down when applied to use; if too hard, the teeth would fly or break off at every stroke; so that very great care and skill are required in the manufacture; and a firm which has once acquired a reputation for good files is extremely solicitous not to damage it by the sale of even one that is defective.

The bars of steel are selected according to the size and shape of the files to be made, and when cut into pieces, each piece is placed among the burning fuel on one of the forges, and quickly brought to the required temperature. Except for the smallest files, there are two men employed at each forge—a *striker* and a *forger*, one of whom manages the fire, heats the steel, and acts as a general assistant; while the other is the superior

Fig. 1.



workman, who hammers the file into shape, and is responsible for its quality. There are various notches, ridges, curvatures, and gauges on and about his small steel anvils, which enable him to work the piece of steel into the proper form for a file, including the narrow handle or "tang." The rate of working is such, that two men can make three thousand dozens in a year, or about seven hundred a week. Each man accustoms himself to the making of one particular size of file, so that in passing along a range of forges, from one end to the other, we begin at the smallest files and go on gradually to the largest. From the thickness and softness of the heated metal, there is very little rebound to the hammer, and this renders the work of the striker rather laborious, especially for large files, where a hammer of nearly twenty pounds weight is used.

The files are then annealed, or "lighted," in order to bring the steel to a state of softness fitted for the cutting of the teeth. This is done by placing them on a kind of brick hearth in a furnace, and exposing them for several hours to a temperature determined by experience; then, without removing them, they and the oven are allowed to cool very slowly, by which the steel becomes annealed to a softness suitable to the subsequent operations.

Next succeeds the process of *grinding*, whereby the files (or "blanks," as they are yet termed) are ground down to a true and regular surface, whether that be flat or curved. This is effected by means of grindstones of different sizes. Each grindstone is occupied by one man, who sits astride over a "horse" or beam behind it, and leans over the grindstone, applying the file to the surface of the revolving stone in such a manner as to grind the former to a true and correct form. The process is wet and

dirty, from the mixture of fragments of stone and steel with the water used in wetting the stone; and the attitude in which the grinder works renders the process rather a laborious one.

Then ensues the very important and curious operation of cutting the files, one which has hitherto defied the powers of machinery in an extraordinary manner. In most file-works there is a long room in which file-cutters are ranged round the sides in front of the windows, each one having a small bench before him with a simple apparatus for fastening down the file while being cut. The men range themselves according to the kind of file which they are cutting, each man confining himself pretty nearly to one size of tooth, and all placing themselves in the gradation of these sizes.

The file being slightly strapped down, the cutter takes a sharp tool or chisel in the left hand and a hammer in the right. This tool is a very hard, sharp, and tough piece of steel, having an edge fitted to produce the required kind of tooth, and a head to receive the blow of the hammer. The hammers employed (the heaviest of which weigh about nine pounds each) have the handle placed in a remarkable manner with respect to the head, being adapted at such an angle that the cutter can, while making the blow, *pull* the hammer in some degree towards him, and thus give a peculiarity to the shape of the tooth. If the file is a flat one, or has one or more flat surfaces, the cutter places the small steel tool on it at a particular angle, and with one hammer-blow cuts an indentation. He then, by a minute and almost imperceptible movement, changes the place of the tool, and makes another cut parallel to and a short distance from the first: then a third, a fourth, and so on to the end of the file, shifting the file slightly in its fastening as he proceeds. Generally the file is cut doubly, one set of cuts crossing the other at an angle more or less acute. In this case he reverses the position in which he holds the cutting-tool, and proceeds as before. If the file be round or half-round, or have a curved surface of any kind, he still uses a straight-edged cutting-tool; but as this can only make a short indentation, he has to go round the file by degrees, making several rows or ranges of cuts contiguous one to another.

Such is the art of file-cutting; and it contains many points worthy of remark. In the first place, the angle at which the cuts are made depends greatly on the purpose to which the file is to be applied, and is made an especial object of the cutter's attention. In the next place, the cut is not a mere indentation, made without reference to form; it is a triangular groove of particular shape, the production of which requires a most discriminating tact in the management both of the hammer and of the cutting-tool. Then, again, the strict parallelism of the several cuts can only be brought about by practised accuracy of hand and eye, since there is no guide, gauge, or other contrivance for regulating the distance. In a round file, too, the several rows or cuts are brought side by side in such an exact manner, that it is difficult to conceive them to be formed singly, and by hand. We may adduce, as an instance of what skill and long practice can effect in this respect, a file about ten inches long, flat on one side and round on the other; the flat side is cut with a hundred and twenty teeth to an inch, so that there are about twelve hundred teeth on that side; the round side has such an extent of curvature, that it required eighteen rows of cuts to compass it; each little cut on this side is not much above a twentieth of an inch in length; and the number is thus so great, that for the whole file there are twenty-two thousand cuts, each made with a separate blow of the hammer, and the cutting-tool being shifted after each blow!

It may well be asked—Why is not this done by a machine? Machines in great number have been suggested, in France, in England, and in the United States; some by mere theorists, some by practical men; some have never extended beyond the drawn plans, while some have actually been set to work. Yet, for some reason or other, all these have failed to maintain their position; they have been tried, commented on, admired, and rejected. Not long ago a very ingenious machine, invented by a gentleman of high mechanical skill, was talked of highly in respect to its fitness for this purpose. But we believe that, at the present time, the whole of the files made at Sheffield (the head-quarters of the trade) are cut by hand. The grounds of this want of success involve matters too technical for us to enter upon here; but we believe that one difficulty lies in this point—that if one part of the file happens to be in the slightest degree softer or narrower than the rest, any machine employed would make a deeper cut there than elsewhere; whereas a workman, who has been in the trade from a boy (and none others, it is said, can acquire the requisite skill), can feel instantly when he arrives at any variation in the quality or condition of the steel, and at once adapts the weight of his blow to it.

When the files are cut, they are brought into the warehouse to be stamped with the corporate mark of the firm. They are next *hardened*, the steel having been before purposely rendered soft for the facility of cutting. This hardening involves details of some nicety, and the proper working of the file depends a good deal on the manner in which it is done. In most of the file-works is a long tank or trough, containing a saline liquid, and behind this are hearths for heating the files. When each file has been heated to a certain temperature, it is plunged suddenly into the liquid, and, while yet warm, is straightened by a small apparatus at hand. A mixture of ale-grounds, salt, and other substances, is also employed during this process.

The files are then scrubbed clean by women with sand and water; and lastly, pass into the hands of the foreman, who tests every file singly, in a way which brings both the hearing and the touch into exercise. He strikes the file gently on a piece of hard steel, and also rubs it gently from end to end; from the sound he judges whether the internal quality of the steel is good; and from the tremulous movement or friction, he judges whether it is tempered to the degree of hardness required; nay, it is said that, even if deaf, an experienced man could tell this by the tremulous motion given to his fingers and wrist!

SAWS.

Saws of the commoner kind are made of thin sheet-iron, planished, or hammered all over, to give a certain degree of stiffness and elasticity. Those of a better quality are made of shear-steel; while the best are formed of cast-steel. We will

Fig. 2.

suppose that the last-named are the object of our attention. The flat ingots of steel, as cast in the manner described in the last chapter, are rolled between ponderous steel rollers, while red-hot, into the form of sheets, the proper thickness of a saw. Many of the Sheffield firms carry on no other occupation than this of rolling bars of steel into sheets.

Trunks.

When the sheets of steel are brought to the workshops of the saw-maker, his first operation is to cut the sheets into pieces the proper size for the saws to be made. This operation of cutting is performed by means of a very stout pair of shears of peculiar form. A man holds the sheet of steel in such a position that the shears may act upon it, moving the sheet from time to time as the cut extends; while another works the shears. The edges of the pieces of steel are then made quite straight by means of a grindstone; and matters are ready for the making of the teeth. This is not done by a file, as some may suppose, nor by stamping out all the teeth at one blow, as others may imagine, but each tooth is punched out separately. There is a kind of flat bench, so arranged that a steel-cutter works vertically against a steel die; and by placing the saw-plate between the cutter and the die, one tooth is cut out at each movement of the fly-press connected with the cutter. The saw-plate is then shifted a little, and another tooth cut out in a similar manner, and so on until the whole of the teeth are formed. These teeth of course vary in size and shape, according to the kind of saw to which they belong. In the saws for an ordinary saw-mill, the teeth are generally right-angled triangles; in the pit-saw, the teeth are so formed as to meet the fibres of the wood at an acuter angle; while hand-saws, and the generality of carpenters' and joiners' saws, have teeth midway in form between the two other kinds. The teeth, after being cut, are finished up with a file, and the burr, or raggedness of the edge, is removed. The steel then undergoes the process of "hardening," which, at some stage or other, is the case with nearly all steel goods. The saws are laid flat in a furnace fitted for their reception, and heated to a degree determined by experience. They are taken out of the furnace, and immediately plunged into cold oil (or into some prepared liquid), whereby they are quenched, and made to acquire a sudden and very considerable degree of hardness.

When the saws, or "plates," as they are called, are removed from the hardening trough, part of the oily mixture is wiped from the surface, while the remainder is dissipated by holding the saw over a clear coke fire; this heating, at the same time, gives the proper degree of temper or elasticity to the steel. While yet warm, the steel is hammered at different parts, to remove any warping or bending which it might have suffered. Then follows one of the most noisy operations connected with the manufacture, viz., the "planishing." The saw is held in the left hand of the workman, rested on a small polished steel anvil, and hammered repeatedly on every part of the surface with a small hammer, whereby a clatter is produced from which a stranger gladly escapes. The object of this process is to make the saw true, even, and of equal elasticity in every part. The operation requires a great deal of dexterity; for the workman, by giving to the saw a kind of vibratory motion as he goes on, tests the elasticity and tension of the steel, and acquires by habit the tact of knowing where to strengthen the weaker parts by increasing the number of blows.

The saw is then carried to the "wheel" or grindstone, where both surfaces are ground all over, to reduce them to an even and regular state; this process having relation to the outer surface of the saw, while the planishing relates more to the internal texture. The grindstones employed for saws are of large size, sometimes as much as six or seven feet in diameter. The saw is too thin and flexible to be held against the grindstone as a knife would be; it is therefore fixed lightly to a board, and the board so held by the grinder as to bring the saw in contact with the edge of the stone, shifting to and fro until every part of both surfaces has been ground down level and true. As saws of the larger sizes could not be conveniently held in this way, they are suspended at both ends by cords from the ceiling, and swung backwards and forwards to bring them to the proper positions. The peculiarities attending this process are very exactly portrayed by Mr. Holland (in his Treatise on the Iron and Steel Manufacture), in the following words:—"It is not easy to conceive the idea of muscular exertion, imminent danger, and peculiarity of attitude, presented to the eye and the mind of an individual who, unaccustomed to such a spectacle, looks at a saw-grinder when at work, standing on tiptoes over a great grindstone revolving with a fearful rapidity; his arms outstretched towards the extremities of the board under which lies the saw, and pressing against it with his knees to keep it in the closest contact with the surface of the stone; his person and dress appearing at the same time as if they had been dipped in an ochre-bed, present a picture of no common interest."

This grinding, though it gives one kind of regularity and equability to the saw, deranges it in respect to another; for the steel requires another planishing, or hammering on an anvil, to restore it to the flatness and straightness which the grinding had disturbed. After this second hammering it is passed over a small coke fire, till a particular and carefully-tested degree of "temper," or elasticity, is given to it. Another grinding, but much slighter than the former, takes out the marks of the hammer, and gives a uniformity of appearance.

There next ensues a process so slight, so simple, and so soon ended, that it would seem hardly necessary to give it a separate place in the description, but it at the same time so remarkably illustrates the tact acquired by long practice, that a stranger is likely to be more struck with this than with any other part of the operations. If we look at the teeth of a saw, we shall see that half are bent in one direction and half in the other, every alternate one being bent differently. This is done by the blows of a hammer, one blow to each tooth. The saw is rested flat on a steel anvil, and held by the left hand of the workman, who has a very small hammer in his other hand. With this hammer he strikes the sides of the teeth, one at a time; the weight of the hammer, the shape of the hammer-head, and the force of the blow, being just such as will enable one blow to give the required bending to the tooth. But the point worthy of note is the rapid and unerring manner in which the workman proceeds along the saw, *missing* every alternate tooth, striking one blow on each of the others, and yet advancing from one to another almost as fast as the eye can follow him. He then turns the saw over, and bends the other half of the teeth in a similar manner, but in an opposite direction. There is a kind of bevil or slope in the small anvil to effect a bending in the teeth of the saw.

BOTANY.

CHAPTER VII.

ORGANS OF REPRODUCTION.

Certain plants take the name of *proliferous* (*proles*, offspring, and *fero*, to bear), in consequence of a capacity to produce separate individuals from detached parts. The flowering currant, for instance, or the gooseberry, allow of generation, to a certain extent, by the artificial process of propagation. A branch on the lower extremity of its axis, while still attached, is broken without separation, or any shoot is at once removed; and, when the parts of junction are inserted into the ground, roots and spongioles become duly formed, which supply the scions with independent means of subsistence. A limited number of garden flowers, such as carnations, are usually treated by summary separation, then called slips, with equally successful results. The common thyme, when it would fail, is continued by the superimposition of soil on the middle of its absorbent extremities. Budding may take place in cauline incisions, or on the edges and in the axil of leaves, as in Bryophyllum calycinum, Malaxis paludosa, and several species of Gesneria, Gloxinia, and Achimenes; but separable buds assume independent growth by roots in Alliums, Trifoliums, and others, as well as in the Alpine grasses, Festuca, Aira, Poa, &c. In addition to these modes of propagation by layers, by cuttings, pipings, and suckers, and by budding, plants may be multiplied by grafting and marching, and by a division of roots and tubers; and there are few species that are able to resist increase by one or other of these methods. It has been observed, however, that the roots of such plants differ in direction from those of seeds, by a tendency to develop in the line of the trunk.

There can be no doubt, indeed, that generation by division

is natural to many plants, such as sugar-cane by its stem, strawberry by runners, and potatoes by tubers; but besides, that in the majority of cases in which shoots are actually propagated, the intervention of a voluntary agent is required, all these species are furnished with seeds for their own increase. The independence of shoots is thus, at best, a phenomenon supernumerary in its character. It may be also shown, on physiological principles, that their efficacy is a secondary result, consequent on a primary capacity of seeding in the parent plants. The process does not enact a reproduction in the proper sense of the word, but a simple continuation, and this is an important difference, worthy to be particularly observed. The rationale, however, does not lessen its marvel; for the rudimentary cell comes before us as the instrument of growth, and the vegetable artificer that developes increase of mass from one type on to a second. The forms of individual life made efficient by propagation owe themselves to the dynamizing influence of cells—to that specific law by which an original vesicle enlarges and conforms its interior atoms to its own pattern. Now, grafting and budding are attributable to the action of a cell already developed in the slip amalgamating with its adopted trunk, and which grows and arranges offshoots until its vital resources are exhausted. For the purposes of reproduction, on the other hand, a different plan is pursued; a confluence of germ and sperm being required, two cells exerting a mutual effect on each other, so as to give rise to an entire and distinct body, into or from which living attachments may be made and supported on proper affinity.

Nature, therefore, has perpetuated the world of plants through an agency neither partial nor contingent. In the course of these chapters, some of the leading organs of vegetation which regulate the growth have been already noticed; but in every plant are inherent organs of reproduction, which, by an appointed self-action, secure the populousness of species. We will now, therefore, turn the attention of the reader to those curious structures which are destined to play so important a part in the clothing of the globe.

Among the simpler forms of plants, reproduction is carried on by the instrumentality of spheroids, usually called sporules or spores (σποϱὰ, a seed), and sometimes thecæ (θήκη, a sac). Of this nature are the Algæ, Fungi, and Lichens, the Mosses, Lycopodii, and Ferns. In the Algæ, &c., they are destitute of a proper covering or receptacle, and, for the most part, are merely diffused through the tissues of the plant; but, in the Mosses, &c., they appear in a somewhat elaborated form, by being invested or encased. These latter spores seem to become productive by the contact of two cells of different kinds; and those who are inclined to pursue in them the idea of fructification, call the one cell by the name Antheridium, from a putative function of anthers, containing granular matter; and the other Pistilidium, containing germinating matter. It is not, however, agreed amongst botanists, whether the spores owe their formation to the agency of sexes; it is certain they are not multiplied from bodies constructed like stamens and embryos. Each reproductive cell contains variously-coloured points, called endochrome (ενδον, within, and χϱωμα, colour); and one envelopes others, so as to become a *sporangium* (σποϱὰ and αγγος, a vase or vessel), that is, a spore case, while the vital spores are included within its cavity. At the first stage, the sporangia are furnished with two or more marginal filaments, or vibratile cilia, by means of which they are enabled to move about in the fluid juices of the plant, or in the sea, when discharged from Algæ; but, after germination has taken place, these are absorbed. In Riccia glauca, the sporangia are immersed in the substance of the plant; in Mosses, they are supported on stalks or setæ (*seta*, a bristle); in short, they exhibit various modifications. The endochrome, again, is sometimes—as in Meloseira—placed on the same individual; in other cases, it diffuses itself separately. In Confervæ there is a conjugation of cells, from which the contents of the one pass, by the formation of a tube, into the others. In Diotomaceæ, the germinating bodies are placed on the outside of the cells. In Zygnema, their position is interior. The following list of Fern spores may be referred to as a guide for the selection of specimens to be examined by the microscope:—

Adiantum nigrum.	Lomaria spicant.
——— capillus veneris.	Lycopodium.
Aspidium aculeatum.	Pteris elegans.
Davallia Canariensis.	—— hastata.
Grammitis ceterach.	Polypodium vulgare.
Hymenophyllum Tunbridgense.	Scolopendrium vulgare.
——— Wilsoni.	Todea Africana.

As we leave the *cryptogamia* (κϱυπτὸς, concealed, and γἄμος, union) departments of the vegetable kingdom, another state of things is presented to view in the *phanerogamous* (φανεϱὸς, apparent, and γἄμος) media employed for the transmission of species. Every one has become familiar, in the course of a rural walk, with those brilliant creations which peer in the grass and perfume the air, the gentle flowers, some in buds wrapped up in tunics, and others blushing in naked loveliness. On the outside of each organism is arranged a series of leaves, within which rises a central filament or stem, and around, the stamina capped with tops of prolific dust. These are, in fact, sexual instruments for fertilizing the germ of the future plant. This apparatus may be conveniently categoried under blossoms, fruit, and seed, which are otherwise respectively termed inflorescence, fructification, and embryology. A great mass of nomenclature is connected with each of these themes; but we will endeavour to present the more essential details in the easiest manner.

I.—Inflorescence.

The inflorescence, in its collective state, may be traced with a reference to the formative leaf which ushers it, the stalk prolonged, the bud which becomes developed, and the envelopes which expand upon it.

1. The axil of leaves supplies the place of formation to the buds of flowers, as well as the buds of branches; but the preliminary leaf of the flower takes the name of *bractea*, *bract*, or floral leaf, Plate V., fig. 7. It starts from these points as a cellular projection, and is ultimately extended into a flower, of which the leaf itself is the type. The flower may come to be separated from the flower bud by a flower stalk, or it may be closely applied to it, if sessile; in either case, the position of the bract is at the base, and if intermediate bracts occur, they are properly termed *bracteoles* or *bractlets*. In general appearance they differ somewhat from the ordinary leaves of plants; in several instances, as in Calla Æthiopica, they are enriched with colouring, and, in respect to their attachment, many are persistent, but the greater number are deciduous. They assume the shape of mere scales, or threads, or tufts of hair, in the Crucifera, in some species of sage, lavender, and crown-imperial, and in this form are called *coma*, or *squamæ*. It is these scales which cover the fertile flowers of the willow; they likewise form the capula or cup of the acorn, and the paleæ or white scales of the artichoke. In grasses, the outer scales or husk are commonly designated *gluma*, *glumes*, Plate VII., fig. 10. Where a whorl of bracts exists, as in Daucus carota, it is *general involucre*—Plate VII., fig. 6.—and, if divided into a smaller whorl, it is *partial involucre*, or *involucel*, Plate VII., fig. 7. When one or more flowers are enclosed by a sheathing bract, the case is named a *spatha* or *spathe*—Plate VII., fig. 3—as in Narcissus; and when several spathes occur of smaller size, they are *spathellæ*.

2. The stem of flowers exhibits them either at its apex, as in Little gentianella, or springing from the points in which leaves join the main stem, as in Scarlet pimpernel, or again, branching from the supports which are there produced, as in Biting stonecrop. The general axis, that is, the first stalk of a flower, whether single or clustered, is called *primary*, and by emphasis, the *rachis* (ῥάχις, spine): if there be a *secondary*, or derived stem, immediately supporting the flower, it is the *peduncle* (*pes*, foot)—Plate IV., fig. 13; and if any subordinate stem, again, arises from the last, it is *tertiary* or *pedicel*. The terms pedunculate and pedicellate, in reference to a flower, consequently express the relation of the branch on which it is produced; where a stalk is awanting, the flower, of course, is sessile. Amongst the various forms assumed by the peduncle, may be mentioned the single (Primula vulgaris), subdivided

(Saxifraga umbrosa), flattened (Celosia cristata), spiral (Vallisneria spiralis), and spiny (Alyssum spinosum). It also occurs cylindrical and grooved.

There are two modes of inflorescence peculiar to the arrangement of the axis now mentioned. The growth of the axis is sometimes terminated by the production of a flower on its anterior or upper extremity; but in other instances, as in Geranium, Rosa, and Geum, it is prolonged in a variety of ways beyond the first flower. The floral axis, therefore, shall be found in practice either bearing a single flower at the end of the stalk, and if there be more, always subsequently producing them lower down on the axis, then called *definite*, *determinate*, or *terminal* inflorescence, which developes itself centrifugally, from the top towards the bottom; or if the axis continues to grow beyond the first flower, producing flowers from above, it is named *indefinite*, *indeterminate*, or *axillary* inflorescence, which expands its buds in centripetal order, that is, from the circumference inwards. In the one, the progress of formation is subject to various derangements; in the other, the parts are formed successively without interruption.

As to the *definite* mode, where a terminal flower takes place at the end of the axis, the common poppy may be referred to as an example. Numerous flowers, however, may be produced even on one or separate axes, if their original direction, as in Erythrea centaurium, is from the same bract which developes the first buds, or from floral leaves placed below the central flower. The central flower expanding first, the expansion is thereby centrifugal. But each branch may be stopped in its growth after producing a single flower; it is then forced to vegetate laterally, and these lateral branches are themselves stopped after forming one flower. This whole system receives the name of *cyme*, Plate XI., fig. 7; and *cymose* is the character applying to it, as in the elder-tree. When the expansion takes place in the Pink tribe, it is denominated *fascicle*, Plate X., fig. 2; in the Labiatæ, Dead-nettle, and Wild Margoram, the clusters are called *verticillasters* (*verticillus*, *a verto*, a little whorl), Plate X., fig. 1; while the curvations apparent in the Boraginacea are named *helicoidal* (ἕλιξ, a ring, and εἶδος, form) or *gyrate*.

The axis of a flower is *indefinite* when the flowers are developed from a succession of floral leaves springing upwards from those of the first flower. If, by a contraction of the axis in this case, a broad disc be formed upon it, as in sea-pink, dandelion, &c., a *capitulum*, or head, or tuft occurs, Plate X., fig. 10; called also sometimes, according to the length of the pedicels, or the convexity and concavity of the receptacle defined, *calathium*, (καλάθιον, a little basket), as in daisy; *glomerulus*, a ball, as in Dipsacus; and *hypanthodium* (ὑπὸ, under, and ἀνθὸς, flower), as in Dorstenia. When several secondary axes arise from the flattened surface of the extremity, whether each ends in a single flower or repeats a radiation of flowers of nearly equal length, circled like an umbrella, it is an *umbel*, as in hemlock; and allied plants, fennel, parsley, &c., are consequently named *umbelliferous*. *Corymbus*, *corymb*, Plate XI., fig. 9, approaches the mode of flowering of the umbel, but is distinguished by the unequal length of the footstalks, which proceed, not as in the latter from the same centre, but from different parts on both sides of the stalk. When nearly equal pedicles, terminating in single flowers, are given off at one point from the primary axis or peduncle, the result is the formation of a *raceme* or *cluster*, Plate X., fig. 4, as in the currant and grape. If the peduncle diverges, the branching inflorescence becomes then a *panicle*, Plate X., fig. 5, as in London-pride, oats, &c. *Thyrsus* or *bunch* is a closer form of panicle, contracted into oval dimensions, as in lilac, &c., Plate XI., fig. 6½. But if the peduncle be really awanting, or from its shortness difficult of recognition, the sessile flowers, as in Plantago, form a *spica* or *spike*, Plate X., fig. 3½, which is further characterized by the following modifications. When the spike is succulent and sheathed, either simply or branching, it is a *spadix*, as in palms; when bearing unisexual flowers, usually males, and suspended by an articulation, as in hazel, it is an *amentum* or *catkin*, Plate VII., fig. 2; and when producing only female flowers covered with scales, it is either a *strobilus*, Plate XI., fig. 13, as in hop, or a *cone*, as in fir. Among the grasses, many florets arise in one calyx, and this arrangement, presenting small spikes, is called *spiculæ*, spikelets, or *locustæ*, which either cluster on the rachis, or branch on a panicle.

3. The development of the leaf-bud is called vernation; but *Alabastrus*, *rose-bud*, is the general term applied with reference to the flower-bud. The period of its spreading is called *anthesis* (ἄνθησις, flower opening); and when the promise has passed into progress, the manner of arrangement followed by the parts receives the title of *æstivation* (*æstivus*, pertaining to summer), or *prefloration* (*pre*, before, and *flos*, flower).

If the bud be carefully removed, we should find the summit of the axis on which it was fixed to manifest certain forms incipient of it. The instrument which would then meet the view, is a nearly horizontal disc, on which the whorls or rotations of flowers were destined to be arranged, and receives the general appellation of *thalamus*, bridal chamber. It is full of minute organisms in the midst of growth, exhibiting cellular papillæ in a ring form. The centre is occupied with the summit of the *receptacle*, to which all the parts of the bud are attached. The *torus* is that part of the receptacle which is situated between the calyx and pistil, and forms a common base to the corolla and androcæum. The *androcœum* (ἀνὴρ, male, and οἰκίον, habitation) is the verticillar base of the stamens. *Nectaries* are glands which are generally produced by the torus, and situated immediately or depending on it. But we content ourselves with the most general allusion to these structures in the meantime, as our references shall be better understood, if considered at a subsequent stage, in the light of a more complete development.

Supposing, therefore, the bud to be again resumed on its axis, we will merely pursue its general relations. If taken as a whole, it supplies the means of exhibiting its arrangements. When the parts of a whorl are of nearly uniform height, and disposed in a circle, the following characters apply: —The æstivation is *valvate* when they adjoin by their edges; if the edges at the points of junction be turned inwards, as in Buglos, it is *induplicate*; if outwards, as in Euphorbia, *reduplicate*; and when in a circular whorl, as in carnation, the parts overlap each other, it is *contorted*; but when, by a difference of level in the parts of verticils, each part spirally covers a portion of another, the æstivation is *imbricated*; when the parts cover each other completely, it is *convolute*; and when the imbrication is such, that out of a whorl of five parts two are external, two internal, and the remaining one covering and covered by the others in turn, it is *quincunxial*.

But the verticils are further characterized as they regard each other. The different series of leaves composing a flower, are not only arranged on a principle of alternation, but are mutually symmetrical in point of number. The most general numbers which prevail are either 5 and 4, or some of their multiples, in Dicotyledonous and Exogenous plants; 3, or its multiple, in Monocotyledons and Endogens; and 2 and 4, or their multiples, in Acotyledons and Acrogens. Thus, if a calyx consists of 5 parts, the alternating corolla shall usually have 5 also; the stamens 5, 10, 20, &c., and the pistil 5, or some multiple of 5. And so in like manner with the rest of the numbers.

4. The floral envelopes, arranged on the edge of a depression at the termination of the axis, are four in full enumeration— the calyx, corolla, stamina, and pistils. They consist of whorls or verticils of altered leaves, fitted for the separate functions invested in each; and each, therefore, is equally essential, according to its combination, for the purposes of reproduction. Among different species, their association is found to be variable for this reason: there is no integument, for example, over the fructification of the willow, and the sexual organs are separated in the hazel. The envelopes are usually divided into outer and inner, the one division embracing the first two of the series, and the other the remaining two. The blossom may be popularly said to comprise the two outer coats—the external, called the calyx, and the next inner, the corolla. Plants distinguished by the presence of both these parts, are on that account known as *dichlamydeous* (δὶς, twice, and χλαμὺς, cloak); when one of them becomes abortive, in which case the calyx is always left, it is *monochlamydeous* (μονος, single); but when

both are absent, *achlamydeous* (α, privative). In many garden fruits, such as gooseberry, currant, apple, pear, and pomegranate, the base portion of the calyx is united, not to the corrolla, but to the pistil; and after enlargement, its upper portion appears at the apex of the fruit. In Composites, Teazleworts, and Valerianworts, the calyx also adheres to the pistil. In certain cases of Endogens, a seeming amalgamation, from colour or other causes, betwixt the calyx and corolla, makes it not easy to distinguish these parts; and to avoid ambiguity, *perigone* (περὶ, around, and γυνή, female) or *perianth* (περὶ, and ανθος, flower) are synonymous terms employed to denote them. The perianths of the crocus, hyacinth, and white waterlily are thus spoken of.

AGRICULTURE.

CHAPTER XII.

II.—THE PLANTING AND MANAGEMENT OF THORN HEDGES.

The *Cratægus oxycantha*, or common hawthorn, is unquestionably the best plant for making fences. It is qualified for this purpose by its hardihood, which enables it to stand our severest winters; its sharp thorns, which render it a perfect obstacle to cattle; and its non-spreading roots. It is, too, a very long-lived plant. Although employed by the ancient Greeks as a fence, its use is not, even yet, so extensive as it ought to be. It is of comparatively recent introduction into Scotland, the first that were grown in that part of the island being planted by Cromwell's soldiers.

It is too common to mix with the hawthorn, beech, sweetbriar, and, in many parts of the country, a great variety of hedgerow timber trees. There can be no doubt that all these additions are injurious.

The season for planting thorn hedges is the winter, and the sooner the planting is begun in this season the better, although it may be continued until March. The old plan used to be to plant them upon lea, but it is now decided, by a sufficient authority, that the ground upon which it is intended to place thorn plants had better have been fallowed, and limed, and manured, about a month before operations are commenced. The first thing to be done is to draw the line north and south, in which the hedge running in this direction is to be. This is best done by the aid of a compass, always recollecting that the variation of the needle in this country is about 27° W. The lines east and west are made to run at a right angle with these north and south ones, employing the instrument called a cross-table. Thorn plants are prepared in the nurseries, and they are not fit for the purpose of the hedger until they have been transplanted two years from the seed-bed, and until their roots have attained a foot in length, and the stems have as much. Such plants as these are usually sold at about half-a-guinea a thousand. They are delivered out from the nurseries in bundles, each containing two hundred; and when they arrive at the farm, their roots are sunk in earth, to keep them healthy until the day they are wanted for use.

The implements necessary for making hedges are a garden line, picks, shovels, and spades.

The direction of the hedge having been determined, the garden line is extended, and firmly fastened at both ends by its reel and pin. A ditch is then dug between this and a parallel line, about four and a half feet distant, the earth being thrown up on one side, to form a thorn-bed for the young plants

The young plants are then prepared for being put into this thorn-bed, by having the small branches and the stem, down to within about six inches of the root, cut away. They are then inserted into the thorn-bed nearly at right angles, but the stem inclining a little upwards.

When spring comes on, thorn hedges require pruning. This is done with a switching bill. The operator holds this in one hand and strikes upward, and just as the stroke is finishing a little backwards. A young fence should not be switched until it has attained a considerable size. If, when the plant has acquired a firm hold of the ground and a due size, it is not regularly pruned, it grows to a considerable height, and acquires altogether the habit of a tree, throwing out its branches from above, and becoming branchless below. When this is the case, it ceases to be of use as a fence plant.

Sometimes, however, a hedge of thorns will become too luxuriant. If this is the case to a moderate extent only, it is severely pruned; but the stems and so many of the branches are left. But if the hedge has got very luxuriant, it is cut down right to within an inch or two of the ground, and in either case a number of new branches strike out, which, if judiciously managed, soon form a good fence.

At the same time that the fences are pruned, the ditches are scoured, and the hedge bottom rendered thoroughly clean.

When gaps occur in thorn hedges, they may be filled up by planting young thorns, or be plashed, as it is called; that is to say, a strong stem is laid down from one side across the gap.

As the summer comes on, the hedge bottoms require to be assiduously weeded. This process is too much neglected. It is the hedge bottom that affords the nursery to a vast variety of weeds that are very injurious and troublesome to the farmer, and which will, if allowed to seed, propagate among the fields, and cause a hundred times as much expense to eradicate as would have sufficed to eradicate them by thoroughly weeding hedge bottoms. It is believed, too, that the turnip-fly depends mainly for its food upon hedge-bottom weeds during the earlier part of the season, and this gives us an additional reason for keeping clean, and free from weeds, the hedge bottoms.

III. STONE WALLS.

The extent to which stone walls are used for the purpose of enclosure, entirely depends upon the supply and relative cheapness of stones. They do not look so pretty as thorn fences, and, strange as it may seem, they allow far more air to pass through them, and hence are not so warm to stock. In other respects, however, they are superior. They take nothing from the ground, and do not harbour so many weeds. Moreover, they require far less labour to keep them in order.

A very common height for a stone wall is four feet nine inches, and its thickness at the base is two feet, which diminishes to fifteen inches under the cover. Such a wall as this, where stones are cheap, costs for material and labour about a shilling a yard.

The first step taken in building a stone wall is to remove the upper soil, as the heavy stone wall is sure to sink in soft earth and to become twisted, and ultimately to fall. The stones are then laid in a heap convenient to the workpeople. Some of the larger stones are usually selected to form the bottom, and the workpeople build in the other stones until a sufficient height is obtained, and then the copestones are put on.

A stone wall of this height will scarcely confine blackfaced sheep, and when they are kept, the wall must either be made higher, or, if this expense be grudged, some other expedient must be adopted. Perhaps the best is to sow whin seeds in the soil behind the wall, and the plants of which will in time reach over the copestones and form a hedge. And these shrubs may come in very useful for feeding horses.

Every year, before cattle or sheep are put to pasture, stone walls should be examined, and all defects in them at once made good. If this be neglected, a very trifling damage soon becomes a very serious one.

IV. WIRE FENCES.

Of late years, wire fences have been a good deal used. They are very suitable for separating pleasure grounds from fields, inasmuch as they form an almost invisible fence. But for farm purposes they are not applicable. Horned cattle are constantly getting fast by the horns in them, and pulling them to pieces, and almost all kinds of stock, deceived apparently as to their height, try to jump them. The writer of this had once a wire fence, which separated the pleasure ground before his house from a meadow kept in permanent pasture, where a few dairy cows were kept. He is sure that he had, one way and another, to renew it every two or three years, and as hardly a day passed without something happening to it, it presented a very untidy appearance. The cost of wire fencing varies according to the height and to the kinds of posts used. From sixpence to a shilling per yard may be put down as common prices.

HISTORY.

CHAPTER XXII.

THE AGE OF NATIONAL GOVERNMENTS IN EUROPE.

The idea of territorial governments—that is, of governments ruling by right over all the denizens of a certain space of territory in virtue of their being born and domiciled within that territory, although it became fully developed, and obtained full possession of the European mind, only during the period at which we have now arrived—the period intervening between A.D. 1519 and A.D. 1788—had been gradually forming for some time before. The principal difficulty that occurs in tracing, or rather in demonstrating the growth of opinion on such points arises from the constant admixture of religious with mere political questions during this period, and their constant re-action upon each other. It is impossible to separate them entirely, and yet it is a pregnant source of error to confound them. For the sake of clearness in treating the subject in hand, we shall observe the following classification of our remarks :—

First,—The progress of the internal organization of the states of Europe.

Second,—The history of the church.

Third,—The relations in which the great states of Europe came to stand to each other, during the period which elapsed from A.D. 1519 to A.D. 1788, in consequence of changes in their political structure and religious faith.

I. Under the first of these heads, we have in the first place to recollect the growth of a national spirit in the great territorial sections of Europe, as traced in the preceding chapter. Similarity of language, occupations, and habits, superinduced by the same climate and the same pursuits, had induced in different parts of Europe that family likeness of character which we call national. So long as the feudal governments continued in their strength and simplicity, it was not conceived that nationality, that is, birth and language, had anything to do with the claim to sovereignty. By degrees, however, as all within a territory came to speak the same tongue, and to be able to trace ancestors who had occupied the same domiciles for generations back, there began to be, in cases of disputed succession, a prejudice in favour of the native candidate. It deserves, perhaps, a less invidious name than prejudice. He who had been from boyhood familiarized to the customs and opinions of the country, and who spoke its language, was at once more likely to respect its institutions, and more accessible to the representations of his subjects. A feeling of identity of lineage, making the sovereign and the people one race, grew up, which, not unfrequently, procured a throne for the claimant, where title according to strict lineal descent was the feebler; and by such incidents, and the sense of mutual protection arising out of them, the identification of national feeling with the government was strengthened. The shock thus given to strict feudal notions was corroborated by various incidents. The invariable tendency of an oligarchy is to resolve itself into either a democracy or a monarchy : to drive the people either into an assertion of their inalienable rights, or into the arms of one great despot, as preferable to a multiplicity of petty ones. The feudal governments were oligarchies : but they were also oligarchies composed of a warrior caste. The more natural mode of dissolving such an oligarchy was for the subjects to throw themselves into the arms of the most powerful of the oligarchs. On the other hand, the feudal over-land hard pressed by the pride and insubordination of his vassals, was ready enough to contract alliances which strengthened his hands against them. It is to this natural law of a society so constituted as that of Europe during the feudal period, that we are to attribute the frequent alliances between kings and the cities or "commons" of their kingdom, against the great vassals of the crown. These alliances conduced to two results :—they strengthened the hands of the executive, and they concurred with the growing enterprise, intelligence, and wealth of the age, to evoke a stronger spirit of self-respect and self-reliance in the breasts of the unprivileged classes. Another circumstance contributed greatly about the same time to strengthen the European sovereigns. Under the fully developed feudal system, the vassals of the crown constituting the army, the cavalry had become the main strength. The incessant wars in which the sovereigns were engaged gradually introduced a system of substitution ; and the demonstration of the strength of infantry by the Swiss cantons in their wars for their independence, from their victory over the throne of Austria at Mergartin in 1315, to their final separation from the empire after the war of 1499, led to the construction of a military force which, being able to keep its ground against the feudal chivalry, diminished the importance of the latter. The introduction and extension of the use of gunpowder in war completed the change of system, and the establishment of standing armies gave the death-blow to feudal government. From the time of their introduction the power of the great vassals decreased ; authority centered more in the hands of the monarch ; but this authority reposing in a great measure upon mercenary troops, rendered money necessary, and thereby imposed upon the sovereign the necessity of conciliating the nation. For the first time since the overthrow of the Roman empire, there existed states in Europe—that is, governments and people incorporated into one organic whole, possessing and occupying a definite territory.

The whole of Europe ripened pretty nearly simultaneously to this condition. Henry the VIIth of England, by marrying Elizabeth of York, united in his heir the rival claims of the two houses which had contested the crown of England, and took advantage of the exhausted state to which the feudal wars had reduced the great barons, to extend the royal prerogative, strengthening himself for this purpose by throwing himself upon the commons tired of the feudal anarchy. About the same time, the marriage of Ferdinand of Arragon with Isabella of Castile, and the overthrow of the Moorish dynasty of Granada—the last of the Saracenic states in Spain—united the whole of the Peninsula, with the exception of Portugal, under one monarch. By giving a new form to the Santa Hermandad in Castile, and introducing it into Arragon, and by vesting in the king the commandership of the three great Spanish orders of monastic knighthood, the authority of the state was in Spain, even to a greater degree than in England, centralised in the royal person. While this revolution—for although the noiseless termination of a protracted and armless struggle, it was a revolution of the importance of which men were not then aware—was effecting in Spain and England, a different train of events was in France conducting to a similar result. Louis XI, by securing a number of the strongest fortresses in his dominions—by keeping on foot a strong body of mercenary troops—by cultivating the good will of the industrious classes—and by losing no opportunity of depressing the great vassals of the crown—was rapidly increasing the power of the sovereign. The kings of England now retained nothing of all their Norman fiefs but the town of Calais. The small feudal kingdoms around the base of the Pyrenees, were on the eve of being incorporated into either France or Spain. The insane pugnacity of Charles the Bold of Burgundy, by involving him in war with the Swiss Confederation, put a sudden close at once to his life, and his ambition of erecting between France and the empire an independent Burgundian kingdom. By his death, Louis was enabled to piece out his domains, and form a more defensible frontier on the east ; and left at liberty to prosecute his attacks upon the feudal privileges of Anjou, Bearn, and Britanny. In regard to the first-mentioned he succeeded ; in regard to Britanny he put matters in such a train that it was easily incorporated with the crown by his successor. The ultimate incorporation of Bearn with France was reserved for the accession of the feudal monarch of Bearn, Henri IV., to the French throne. In Germany the forms of the Empire were still observed. In the person of Maximilian I. the imperial dignity was vested in the House of Hapsburg, in which it continued from that time till the dissolution of his empire. The power of electing the emperor had now been usurped by the great territorial princes, lay and clerical. The knighthood of the empire and the free towns had no voice potential in the election, although they were allowed a voice deliberative in the settlement of the "capitulation," or agreement formerly concluded with every emperor at his election. With every new election the higher territorial nobility extended their privileges until they came to embrace every thing of sovereignty but the name. In Italy, the authority of the emperor had evaporated rather than been overthrown. The intrigues of the Popes—in their capacity of temporal sovereigns—were successful in preventing the union of Italy under one secular head. There was a uniformity of national character in Italy, but there was no organized nation in Italy. France, Spain, and England were nations ; Italy was, as previous to the growth of Roman power, a juxtaposition of small states with kindred language, customs, and morals. Germany was much the same—only the habit of observing the forms of the empire, placed it in point of organization mid-way between the completely organized states of France, England, and Spain on the one hand, and the unorganized nation of Italy on the other. These were, and at the time which we have fixed upon as the commencement of the territorial era, the leading, the more prominent states of Europe. There were some independent minor states filling up the

territorial interstices:—Portugal on the south-west of Spain; Switzerland on the Western Alps; Scotland on the north of Britain. To these several others came to be added in course of time, by the dismemberment of the empire, and the introduction of the countries north of the Baltic. It will be necessary, however, before taking up this part of the subject, and the discussion it leads to, to turn our eyes to the history of the church.

II. During the feudal ages, the Church of Rome, such as we have seen it, was the paramount sovereign of Europe. Its jurisdiction, such as it was, extended over the whole of Europe. In all contests between subjects and sovereigns, or between one sovereign and another, it was in virtue of its spiritual character a natural and unobjectionable referee. By skilful alternation of its services, it contrived alternately to bring all parties more and more into habits of deference to its authority. Beyond a certain pitch it did not dare to assume; for there it awoke, within the rude warriors with whom it had to deal, the remembrance of their superior physical strength. The weapons of the church were intellect and *finesse:* in its struggle for ascendancy, its members displayed as much courage though less straight-forwardness than the generous animals they alternately caressed and chid.

The chief dangers of the church during the feudal period were from within. It was an assemblage of intellectual men—of the most intellectual men of the time. Ambition, the desire of ascendancy in the councils of their corporation, burned perhaps even more keenly among them than among the ruder and less instructed laity. This circumstance, the growth of the national spirit tending to create territorial partisanship within the church itself, and the constant implication of the church in secular intrigues, all contributed to produce the great schisms of the fourteenth century, during which confounded Europe had its spiritual allegiance claimed at once by two rival Popes—on one occasion for a time by no less than three. These unseemly and protracted ebullitions of worldly pride and rancour among men regarded as set apart from the rest of the world by spiritual mindedness, were ill-timed for the perpetuity of the church's power. The faith of many was rudely shaken; and even among those who continued unwavering in their allegiance an ardent desire was begotten for a reform within the church. For a time this reform contemplated nothing beyond a stricter enforcement of discipline, and the introduction of an organization more adequate to its enforcement. This subject was broached in more than one council of the church. Even the Synod of Constance which condemned John Huss to the flames, expressed a conviction of the necessity of reform within the church, and denounced its more prominent corruptions in language more strong than that of the martyr himself. But the evils lay deeper than reformers within the church could discover; and a remedy for them was working its way unobserved into the social system.

We have, in a preceding chapter, indicated the effect of the feudal anarchy, by leaving the cities to govern themselves, to increase activity, intelligence, and wealth. With wealth came luxury and litigiousness—the one reviving the fine arts, the other re-awakening the legal lore of old Rome. Almost co-temporary with the blossom of those invigorating pursuits came the seemingly accidental revival of two older literatures. The success of the Turks in Asia, and ultimately in Europe, drew many learned Greeks to seek refuge in Europe, who brought with them that literature which had been handed down, thanks to the schools of Alexandria, Athens, and Byzantium, by an uninterrupted tradition in the Eastern empire.

Now the cultivation of the taste and intellect, although not of themselves sufficient to form a sound monarchy, are indispensible elements in its first formation; and, although susceptible of bias, the natural tendency of such cultivation, its first promptings, is in the direction of truth, that is, of sound morality. With every step made in art, literature, and science, the atmosphere of public morals became purer and healthier. The number of unfavourable voices raised against a notorious ill-doer became too great, and consequently too powerful, for his comfort. Men made their neighbours better than they were themselves. The main brunt of this novel puritanism bore upon the clergy—not that they were worse than others, but because, according to the theory of their profession, they ought to have been better. The diminution of respect, too, which the church had incurred by the schisms of the fourteenth and fifteenth centuries, made men ready to carp and cavil.

With all this there was no decided hostility to the church. There was a general longing for purer practical morals, both in church and state. Every better and more cultivated mind strove within his sphere to promote this object—the poet by satiric ridicule, or by enthusiastic exhortations—the priest by his preaching—the scholar by his writings. Boccacio and Chaucer are examples of the first; Wickliffe, Huss, Zuinglius, and many who neither incurred, nor dreamed that they were doing anything to incur, the enmity of their church, of the second; Erasmus, of the third. The great cause of moral and intellectual advancement was prosecuted as earnestly by the churchmen as by the laymen.

But the circumstances of the church were rapidly bringing about a total revolution of this state of society. The Church of Rome had for many centuries ceased to consider the doctrinal or teaching part of her functions essential. The style in which whole tribes were converted and baptized at once forbade the idea of their understanding the doctrines of the church. Outward conformity to its rites, and obedience to the special directions of its ministers, was all that was required. The strength of the Romish Church had consisted in its sedulous evasion of most points; but the time was coming when it was to be driven to the wall. To this deficiency in a body of doctrine, the church had latterly united a daily secularizing temper. The organization of Hildebrand, by vesting the supremacy in the Conclave, had thrown the whole influence of the church into the hands of the Italian prelates. The Pope, anxious to keep the power of the tramontane sovereigns aloof from the fields of Italy, had allied himself and his conclave more closely with the powerful and rebellious vassals of the empire. Their temporal support was purchased by promoting their cadets in the church. It was in consequence of this policy that two members of the Medici family—Leo X. and Clement VII.—came to fill the chair of St. Peter successively, between the year 1512 and 1535. These princes—as well as some of their predecessors in the pontificate—combined all the ability, taste, and learning, which seemed almost hereditary in the Medici family, with all its worldliness of policy. Under them the Court of Rome became at once the most refined and the most free-thinking in Europe. But even the treasures of the Church of Rome ran dry under the lavish expenditure of the ostentatious Leo. Mere worldling as he was, it was enough for him that he could procure money to gratify his tastes: the means gave his conscience no uneasiness. He had recourse to a measure, occasionally adopted by some of his predecessors, but never on such a colossal scale, nor for such purely personal ends as by him—the sale of dispensations—wielding the keys of St. Peter for the wages of sin.

This nefarious trade was carried on to an unparalleled extent throughout Europe, at a time when the public moral sense had sufficiently ripened to excite intense disgust at it, and at a time when many minds, themselves unconscious of the fact, were ready to revolt from the Church of Rome. Zuinglius had for upwards of three years been preaching from the Greek Testament, sedulously confining himself to what he found written therein. From Luther's table-talk, it appears sufficiently that opinions incompatible with Romish ascendancy had been silently growing up in the quiet retirement of many a convent. The sceptical spirit had mastered most of the *literati.*

At such a time, the disputation commenced between Luther and John Texel, regarding the sale of dispensations, was as a firebrand thrown into a heap of gunpowder. All who were interested in the abuse were vehement in its defence, and among them there were the Pope and Conclave of Rome. All who had an interest in its suppression were glad to see it rendered unpopular, and among these were the wisest sovereigns of the time, who saw the ready money of their dominions draining off to Rome, and public and private morality threatened with an entire overthrow. The unsophisticated sense of the populace—the inquiring spirit of the learned, were alike favourable to the assailants; and the powerful of the earth, feeling an interest in the affray, took part with one or the other side. It was not a mere doctrinal controversy—it was not even a struggle between authority and the moral sense of the people—it was a political question among those who swayed the world, and used armies instead of syllogisms in their disputations.

The Romish court, of course, took part with their own emissaries, and Luther and his coadjutors were driven to the alternative of yielding, or attacking the authority of the head of the church. Luther was not a man to hesitate or retreat, and the moment he saw the necessity of adopting one or other of these alternatives he made his choice. "Alone he did it." His enthusiastic bravery was contagious, and from every country of Europe men gave in their adherence to his banner. It does not appear that Luther at first contemplated a secession from the church. A reformation within the church was his first object; and even after he had persuaded his great protector, the Elector of Saxony, to sanction the reformation of the churches within his dominions, the utmost extent of his views seems to have been the standing apart of these churches until the others should follow their example, and the European church should be re-united upon a new and better footing.

Towards the close of his life, however, he seems to have grown indifferent to any reunion, and his successors seem to have lost sight of it altogether. Various causes co-operated to produce this effect. The Protestant princes of Germany kept their ground in the first war stirred up against them by the Romish court, and a succession of truces accustomed both Protestants and Papists to see their respective churches existing along side of each other. Except on extraordinary occasions, the active spirit of proselytism is confined to a few: the mass of mankind are contented to go on in the way they have been bred to, and to allow others to go on in theirs. Men educated Protestants felt a much more languid and tolerant spirit than men who had converted themselves from it; and Catholics who had lived from childhood in the same country with Protestants, were not so terrified for them as Catholics who had winessed the genesis of the heresy. The course the reformation had taken promoted this subsidence of vehement proselytism. One source of the strength of the Romish Church, it has been said, consisted in its avoiding peremptory and precise dogmatical definitions. The Protestants—trained in a more precise school of thought, and goaded by the tenets of their adversaries, who represented them as creedless, hastened unwisely to define minutely their articles of belief. By this means many crude and ill-examined positions were assumed; and, what for the moment at least, was more dangerous, violent controversies were engendered among the Protestants themselves. They were as intolerant as all men new to investigation generally are, and as stubborn as was natural in men, the foundation of whose creed was the rejection of all human authority. Even in the hour of urgent peril the Lutherans refused to acknowledge the Swiss reformers as brethren in the faith, on account of their opinions regarding the presence of Christ in the sacrament of the Supper. The question of baptism produced another schism. The Calvinistic modification of the doctrines of Zuinglius took hold on Switzerland and France. Another modification of the doctrines of Zuinglius prevailed in the South of Germany. The views of Luther prevailed in the north of Germany, and to the north of the Baltic. A modification of Lutheranism was adopted in England, while Calvinistic tenets struck deep root in Scotland. The mode in which the external process of church reform was set about in different countries tended also to produce discrepancies ultimately in the views of Protestants. A fundamental tenet of most of the earlier reformers was, that each church was entitled to reform itself, with the sanction and under the protection of the temporal sovereigns of the state. A view so flattering to sovereigns gained many; and the personal character of the sovereign under whom the change was effected, contributed materially to modify the character of the church in each state where Protestantism gained the ascendancy. The Episcopal form was retained in England; a republican party, at least among the clergy, was introduced in the reformed Swiss cantons and in Scotland. The government of the church by central consistories was adopted by most of the territorial princes of Germany, who established the Protestant religion within their dominions. Under these auspices, a modification of Christianity, only less secularising in its effects than the Romish, began to predominate—the habit of viewing the church as a mere engine of state, entirely subordinate to the secular authority. From this we date the conception of national churches as separate from and unconnected with the universal church. Under the territorial governments—as well those in which the Romish faith retained the ascendancy, as in those in which the Protestant has supplanted it—the political influence of the church has been as nothing compared with what it was under the feudal governments.

It has been made an influential war-cry of party, and this in consequence of circumstances which, amid all the deadness that a secular spirit has breathed into all the churches, have kept up an under-current of activity. Amid all the divisions and torpor of the Protestant churches, there was something in them that gave them an advantage over the Catholic church. They were more akin to the notions and temper of the age: they had brushed off old fallacies and superstitions which the Romish dignitaries would fain have got rid of, could they have done so without compromising their church's claim to infallibility. The Protestant churches had fewer untenable points to defend. Again, in those countries in which Protestants existed, although the Romish remained the religion recognised by the state, the necessity of their position forced them to more zeal and activity. An established sect endures by its *vis inertiæ:* even a tolerated sect must keep itself active by incessant exertions. Lastly, in every land, as there has always been since the promulgation of Christianity, there were at all times some, however few, who struggled to be Christians in spirit and in truth, repelled by the dry husks of mere legality and formal Christianity. Some of these—as, for example, the founders of the Society of Friends, the Moravian Brethren, &c.—separated themselves from other churches. Some prosecuted their search after light and truth without withdrawing themselves from the communities to which they belonged. Minds of this spiritual cast are to be found in all churches, but their influence was uniformly found more favourable to Protestantism, inasmuch as in all forms of Protestantism there was less to repel and trammel them than in the Romish church. Hence it came that, although no Protestant church assumed such a position as made it likely it would in time supplant the Romish, the Protestant churches, as a body, were gaining incessantly upon the Romish.

The Romish church was thus driven to have recourse to propagandism in self-defence. Spain was, with the sole exception of Italy, the most vehement partizan of the Romish authority. The causes of this have already been explained. Already under Ferdinand and Isabella, the Inquisition was established; and although the natural feelings of the Spaniards at first revolted against the proceedings of that blood-stained tribunal, habitude reconciled them to enormities which pressed almost exclusively upon the hated tribes of Jews and Moriscees. It was from this land, intellectually energetic enough to produce Celderin and Cervantes, but fanatic enough to endure this inhuman tribunal, that the organization of the most powerful instrument ever wielded by the Romish Pontiff proceeded.

Don Ignatius Loyola founded, in the year 1540, an Association (*Societas Jesu*) which had much more in common with the monastic orders than their common views, but which contemplated a widely different sphere of action. The object of the association was to re-establish and spread the Catholic faith, and a habitual exercise of its principles in life, by taking in hand the education of youth in colleges specially organized for that purpose, by preaching and officiating as confessors, and, above all, by missions among infidels, heretics, and schismatics. Their organization comprehended not only the members of the society, but those who submitted themselves to their spiritual guidance, for whom they arranged affiliated societies, in which every man might make himself useful in his sphere, to promote the views of the members of the society, and to work upon the minds of others. Those alone were admitted to the missionary office, and to share in the government of the order, who, after a long probation, had been declared qualified, and who, in addition to three vows of the monks, had taken a fourth of unconditional obedience to the Pope in every mission entrusted to them. These (*professi quatuor votorum*) constituted the society in the exact sense of the word, which supported, for the furtherance of their objects, besides their educational establishments, professional and prelation houses, seminaries, residences, and mission houses: all differently organized institutions, of which the colleges were the most common. The local superiors staid under the supervision of provincial superiors, and these under a *Praepositus Generalis* of the order, resident in Rome, who co-operated with a council of assistants from the various nations. The order distinguished itself from all others by the more unrestricted power of the superiors, especially of the General, and more systematic application of the peculiar talent of the individual members, all of whom were bound to implicit obedience. The society was intended to be a corporation in which each member not merely acted in conformity to certain rules, but thought and willed in exact harmony with every one of his associates; and, strange though the assertion may seem, this end seems really to have been attained for a short period about the close of the 16th and the beginning of the 17th centuries. Paul III., and his superior in the Pontificate, Julius IV., bestowed extensive privileges upon so submissive an order—exempting it from Episcopal control—and the Council of Trent confirmed the privilege. A new class of spiritual functionaries seemed to have arisen in the Jesuits, which were distinguished most advantageously from the secular clergy and the monks by their learning, by the zeal with which they, like the Protestants, preached from the Bible, and taught its doctrines, and by their assiduity in the instruction of youth. Princes and bishops hastened to make room for such men in the chairs of the universities, in the churches, and in the confessionals. Their assistance was especially invoked in places where it was necessary to counteract the progress made by the Protestant doctrines without the countenance of the secular authorities. They used the same weapons that the Protestants had used to promulgate their doctrines, and the latter were astonished to find their progress checked on a sudden in a manner which they could not by any means understand. It was, however, not so much the influence of the Jesuits with the people that the Protestants had to dread: there they could fight them with their own weapons. The danger lay in the skill and

pertinacity with which they every where sought to undermine treaties between the contending religious parties. They taught that the decision of the Council of Trent had rendered all such treaties null. The Lutherans had only been tolerated until a synodal resolution had been promulgated regarding their controversy; and as for the evangelical or Christian section of the Protestants, as they had never adopted the Confession of Augsburg, they never had any claim to toleration at all. They stormed incessantly the consciences of Catholic princes, exhorting them to set on foot the re-conversion of their schismatic subjects to the Catholic faith. And these exhortations they supported by reference to a favourite dogma of the reformers, that it was the duty of every secular sovereign to reform the church within his own dominion whenever it had wandered from the true faith. Their skilful organization, their learning and activity, made the Jesuits the soul of the party in Europe attached to the Romish church during the greater part of the period at present under consideration. Scarcely a complaint was made by the evangelical party in Germany during the first half of the seventeenth century, in which the Jesuits are not accused of being the authors of the mischief complained of. Their use as a bugbear in England during the same period is known to all. More may have been laid to their charge than they deserved; but there is no doubt that the activity of the Catholic party centered in them.

Next chapter will be devoted to an account of the origin and progress of the international law of Europe, out of the collision of such states, and to a sketch of the moral and intellectual condition of Europe from A.D. 1519 to A.D. 1788.

ON THE PHYSICAL FACTS CONTAINED IN THE BIBLE COMPARED WITH THE DISCOVERIES OF THE MODERN SCIENCES.

BY MARCEL DE SERRES.

ARTICLE I.

The greater part of those who have meditated on the Sacred Writings, have turned their attention rather to the religious ideas contained in them, than to the accuracy and importance of the physical facts exhibited in their pages. Finding in these books, superior to all others that have been written, truths essential to the destiny and vocation of man, they did not think that they ought to seek in them light or information respecting the material world, which has been given to us as a subject for our researches and investigations. They have thought the less of this, because in the eyes of some of them such a consideration appeared alike futile and superfluous.

To make amends for this oversight, we shall concentrate our examination on the physical facts contained in the Bible, and which the sciences have made known to us only a short time antecedent to the present. This we are the more called upon to do, because we have here studied the Sacred Writings only in one point of view, namely, with regard to the positive notions they gave us respecting the whole of creation. We cannot too often repeat that, in the examination on which we are about to enter, we have looked upon Scripture with the eye of a natural philosopher, not of a theologian; the material world has alone attracted our regard.

The most important point, relative to the creation, and of which we have still no knowledge but from the Bible, is the distinction which it establishes between the creation of the universe and its co-ordination. Thus, in the beginning (*in principio*), all the matter which composes the earth and heavens was created; afterwards, this matter was appropriated and formed the stellar and planetary bodies of the solar system, as well as those of other systems.

This appears particularly obvious when we direct our attention not only to the first verse of Genesis, but to those that follow, particularly the 7th, 8th, 9th, and 10th verses of the first chapter. Physical facts demonstrate the accuracy of this interpretation. Undoubtedly the whole of matter had been created at the beginning of things, and probably no new matter is formed. But it was not co-ordinated or organized at the origin of time in its universality; for every day celestial bodies are produced, under our own eyes, which are the result of the condensation of this same matter. It will continue unceasingly to be condensed, and it will form stars more or less complete, as long as any of it remains capable of assuming new forms and new dispositions. If such concretions are still preparing and organizing celestial bodies, it is evident such formations indicate to us that if matter proceeded from nothing at the first, it was not appropriated till a long while after its creation. It is with reason, therefore, that the Sacred Writings have distinguished the creation of matter from its posterior arrangement.

The chaos in which Genesis represents all matter to have been at the birth of the world (and particularly that which afterwards formed the earth), is a proof that Scripture rightly distinguishes creation and co-ordination. This matter, at first without form and void, from which the globe we inhabit arose, would appear to have been analogous to those nebulosities, the condensation of which produces, under our own eyes, new celestial bodies. At every period nature has thence derived the elements with which she has formed the celestial bodies composing the wonderful assemblage of the universe. It is likewise from the bosom of these masses of nebulosities, so abundantly diffused through space, that she draws the stellar and planetary bodies.

This distinction, established by Scripture, is founded on two orders of facts entirely independent on each other, and which, owing to that circumstance, have their weight and authority increased. The first refers to the transformations which take place, in space, between nebulosities and the new stars produced by their condensation. The second has reference to the space of time necessary for the light of the most distant nebulosities to reach us. This space is so considerable, that, according to the observation of facts, we must refer the first emission of this light to about a hundred thousand years before the appearance of man.

If, then, the luminous rays emitted by nebulosities require so long an interval in order to become visible, the stars which transmit them to us must have been created before the last arrangements were made on the surface of our planet. Now, as these rays require about a hundred thousand years to reach us, and as the final dispositions made on the earth do not go back further than seven thousand or seven thousand five hundred years from the present epoch, the stars to which we owe this blessing must have been created at the commencement of things, or, to use the expression in Genesis, at the beginning—*in principio*. An immense interval must therefore have intervened between the creation of the celestial bodies and their co-ordination. This interval is still greater when we turn our attention, not to the stars of the solar system, but to those which form no part of it. In fact, the former are completely terminated; but it is not so with the others. This work has, however, commenced at an era separated from ours by immense periods, and the succession of ages has not sufficed to complete it.

This co-ordination of a matter pre-existing since the origin of things, cannot be considered as a true creation. In this case there is, indeed, a change in the state and form of the original materials, but there is no new production. This production, however, would be necessary, in order that these changes and modifications could properly be regarded as acts emanating immediately from the creative power.

Matter being once created, secondary causes, under the direction of Divine Wisdom, would tend to make it assume determinate forms, and proceed in a regular course. Accordingly, the forces which Nature holds in some degree in reserve, in order that they may be brought into action when any disturbing cause threatens to interrupt the order and harmony of created things, she also destines for acts still more important. Their power, essentially conservative, brings the newly produced celestial bodies into a firm and stable condition—a character distinctive of stars arrived at their perfection.

If the proofs of so many facts, the first knowledge of which we owe to Moses, are written in indelible characters on the strata which form the crust of the globe, those of the truth of the first verse of Genesis are traced in characters of fire on the celestial vault. It is there that we discover the confirmation of it, and perceive its perfect accuracy.

It is true that Moses has not developed the system of attraction in all its extent; but he has fixed its principles, without expressing it in a scientific language which could not have been understood. He leads us at all times to understand that the law of gravitation regulates the phenomena of the universe, that it is sufficient for all, and maintains in it both order and variety. Emanating from Supreme Wisdom, this law has presided, since the origin of time, over the harmony of created things, and renders all disorder among them impossible.

If we represent this universal force as depending on some more general mechanical conception, for example, the existence of an elastic ether diffused throughout the whole universe, there would still remain the *why* of this existence; the second *why* would immediately lead us to another still more remote; and the last of all must remain for ever inaccessible to the efforts, not only of our thoughts, but even of our imagination.

When Scripture speaks of the earth, it teaches us that God has

laid the foundations of it, and that it shall never be shaken; for he has fixed it upon its poles. It then represents to us the terrestrial globe as having passed, in its earliest ages, through the state of a kind of vapour more subtle than the most attenuated and finest dust. If it speaks of its form, it represents it as suspended on nothing, or on a bottomless space. It also correctly describes its dimensions and size.

If it directs our attention to the heavens, it designates them by their extent, *rakiah*. Notwithstanding the accuracy of this interpretation, which represents the immensity of the celestial space, the Greeks, in the Septuagint version, as well as the Latins, in the Vulgate, have presumed to correct it, because they did not perceive the extent of its import, or because they did not understand it.

The heavens, in the Bible, are the immense, infinite space, through which the nebulous matter, the universal source of all the celestial bodies, is diffused. They constitute the *expansum* or immensity, and not the *firmamentum* of St. Jerome, nor the *στερέωμα* of the Alexandrine interpreters, nor, finally, the eighth heaven of Aristotle and all the ancients, which they represent as firm, solid, crystalline, and incorruptible.

Moses alone has distinguished the primitive light from that whose benefits we derive from the sun. He has represented it to us as an element independent of this luminary, and as anterior by three epochs to that when it received its brilliant atmospheres. The distinction has brought many reproaches on the author of Genesis: those who uttered them, struck with the splendour of the great luminary which presides over the day, could not conceive that other sources of light existed both for the earth and for the rest of the universe. But the difficulties which have been felt, as to the accuracy of the Mosaic narration, have not kept their ground before the discoveries of science. In fact, an immense quantity of light is produced here below, and developed in an infinite variety of circumstances, altogether foreign from that we derive from the sun. Of this nature is the light emitted by volcanic fires; also that accumulated on the surface of clouds, which is not an intermittent, but continuous light. This light, produced by their phosphorescence, was sufficiently bright, aided especially by temperature, humidity, and electricity, all of which were more considerable in the first ages, to make vegetables grow, before the solar rays had caused their powerful influence to be felt.

Neither does Moses represent the light as created, as Biblical commentators have unreasonably supposed; but he represents it as bursting forth at the voice of God. The author of Genesis, therefore, is rather in harmony with the theory of vibrations or undulations, generally adopted, than with the theory of emission, which cannot explain the whole of the known facts.

In this point of view, the Hebrew lawgiver would have appeared superior to Newton, if that great genius had not himself been favourable to the hypothesis of vibrations, although, for his explanations and calculations, he adopted the theory of emission. It is in the letter written by him to Boyle that he has endeavoured to demonstrate that the vibrations of the ether, determining the phenomena of light, may furnish an explanation founded on those of weight or attraction.

While admitting a light independent of the great luminaries placed by the hand of God in the midst of the celestial spaces, Scripture does not fail to direct our attention to the magnificence and splendour of the solar rays. We are informed that man cannot endure their brightness, when the winds have cleared the sky, and when the north wind causes the golden sun to shine.

When Moses turns his attention to the numerous stars which impart to night its magnificence and beauty, his knowledge appears superior to that of the ancient astronomers, who, in their imperfect observations, have classified only about a thousand. He, on the contrary, multiplies them to infinitude, and regards them as innumerable. Thus, in a single word, he represents to us the immense quantity of stars which compose the milky way, or which are disseminated through the celestial spaces. Continuing the examination, he compares them, as Herschel might have done, to the grains of sand on the sea-shore. We might not, perhaps, have seen any thing else in these expressions but a simple figure, had not Scripture added, "God has scattered them with his hand in space like dust," and however great their numbers, "He names them all by their names." When not speaking of their numbers, but of the order and regularity of their movements, Scripture compares them to an army advancing to battle. It represents this army as incomparable for the multitude of its soldiers, and the perfection of its evolutions. Filled with wonder at the magnificence of the heavens, the Sacred writer exclaims, in rapture, "They declare the glory of the Almighty; and, although without words and voice, they do not the less proclaim his power and glory."

However brilliant the stars disseminated through the immensity of space, Scripture never supposes them to be animated, as the ancients imagined. Neither does it assign to them any influence over human affairs. It regards them as bodies called forth out of nothing by the voice of God, as inert pieces of matter, regulated and submissive, proceeding with the order, regularity, and unity, of an army advancing to battle, and executing the decrees of his Supreme Wisdom.

Scripture is not less exact when it describes the different constellations. It represents the Pleiades as owing their lustre to a great number of stars placed together. It speaks, on the contrary, of the stars of Orion as remote from each other, and in some measure, as it were, dispersed through the celestial vault. In alluding to the brilliant constellation of the Great Bear, it represents it as composed of an infinite number of resplendent stars.

It is not only when considered in relation to these great views, that Scripture appears in harmony with the discoveries of science; the fact is even more conspicuous when we regard the phenomena of the material world in detail. Thus, when it speaks of the air, it represents it as possessing a certain weight, and surrounding the earth in immoveable layers. In fact, in that admirable song of Solomon's, where he describes the eternity of the Infinite Wisdom, does he not tell us that it existed when God established the air above earth, when he assigned their equilibrium to the waters of the fountains, and laid the foundations of the earth?

In like manner, Scripture first informed us, "That God gave to the air its weight (*mischkal*), and to the waters their just measure." Yet this property of the aeriform fluid which surrounds the earth remained unknown till the time of Galileo and Toricelli. At the most, Aristotle had but a faint idea of it; just as, at a later period, Seneca had some notion of its resilience and elasticity.

This weight attributed to the air has appeared so extraordinary to all the interpreters of the Book of Job, where it is literally stated, that, from not being able to comprehend it, they have altogether misinterpreted it. All of them have translated the expression *rouach*, which properly signifies the air or the aeriform layer which environs the globe, by the term *wind*, although they have preserved its true sense to the word *mischkal*, that is to say, heaviness or weight.

They have been led to do this, because they were unable to conceive that the air could be heavy. The great discovery of Toricelli had not yet been made; and these men knowing from experience that we encounter a certain resistance when moving against the air in motion, they have ascribed weight to it on account of its strength and power. Instead of following Scripture, and assigning to the air itself a certain weight, they have referred it to the agitation and impetuosity of its moveable strata.

The above interpretation once admitted, all commentators who have followed the first translators have adopted the same version, without attempting to ascertain whether it was conformable to the true sense of the Hebrew text.

If the old interpreters had understood the true sense of the 7th verse of the 135th Psalm, they would have found in it an additional proof of Scripture attributing weight to the air. The Psalmist there praises God, "Because he maketh lightnings for the rain, and because he causeth the vapours to ascend from the ends of the earth, and bringeth the winds out of his treasuries." The ascent of the aqueous vapours in the midst of the air, is the consequence of their lightness being greater than that of the atmospheric strata through which they pass. Both the one and the other of them are, therefore, heavy, and the excess of weight is here in favour of that which, at the first glance, would appear destitute of it.

As they are regarded by Scripture, the aqueous vapours are the source of clouds, whence the waters descend which fertilize the fields, or lay them waste when they are too abundant. They are, therefore, the cause of the impetuous rains and storms, when they afford a free passage to the lightnings of thunder. Scripture thus recognises their density, and that of the aeriform stratum which affords them access to the middle of its interstices.

The Bible thus represents to us the aqueous vapours as constantly suspended in the air, and nature, by an admirable system of circulation, as employing these vapours in the production of clouds, the source of the rains which fecundate the earth. Scripture assigns to the atmosphere and to the upper waters, that is to say, to the aqueous vapours suspended in its bosom, an importance which modern science alone has been able to establish. At least, according to the calculation of the greatest natural philosophers, the force annually employed by nature in the formation of clouds, is equal to an exertion which the whole human species could not accomplish in less than 200,000 years.

This "separation of the upper waters from the lower waters,"

has taken place by means of the atmosphere, and not by a solid sphere, as the greater number of the interpreters of Genesis have erroneously supposed. In fact, the Hebrew word *rakiah*, which we have rendered by *interval* or *firmament*, is far from having the least relation to anything firm or indurated. It rather designates a vapoury space, that is to say, an aeriform layer, but by no means a heaven of metal, as Don Calmet has unreasonably imagined.

The Bible here indicates to us the importance of water in the formation of the earth. It further informs us that, besides the water diffused through the atmosphere, or which covers the greater surface of the globe, there exist quantities, not less considerable, in the interior of the globe. Its solid crust, it is stated, covers a great abyss: from this abyss the waters made a violent eruption at the period of the Deluge, as at the time of chaos, and the innumerable ages which had preceded it.

Thus the Sacred Scriptures, antecedently to modern discoveries, show us the exterior crust of the earth issuing from the bosom of the waters, and this same crust enclosing in its interior an immense quantity of water in a liquid state. These facts have been confirmed by observation and science. Is it not consistent with common experience, that subterranean waters are almost as abundant as those which flow on the surface of the earth! The globe would appear to contain in its interior, rivers, torrents, lakes, and perhaps even seas. When the Bible speaks of the Deluge, it represents it as produced by impetuous and violent rains, the flood-gates of heaven being opened. On the other hand, it describes the waters enclosed in the bowels of the earth, as having gushed up to the surface in torrents. They swelled, at the same time, the exterior waters, which accumulated and overflowed on every side, according to the energetic expression of Job. All these causes united produced this terrible catastrophe, which brought destruction on the human race, and which was followed by their renovation. Such facts are still the cause, not indeed of deluges analogous to that the violence of which the Bible describes, but of inundations which afflict and desolate the earth at distant and rare intervals. The waters of the heavens are incapable of producing them, as they were incapable of causing a cataclysm, such as that which occasioned the destruction of man. In fact, the quantity of aqueous vapour diffused through the atmosphere is too inconsiderable to produce deluges resembling that of Noah, the extent of which physical facts sufficiently attest.

Scripture does not confine itself to these particulars, in order to enable us to understand that. besides the great masses of water spread over the surface of the globe, there exists others not less considerable in the interior. The earth is founded and stretched out, it informs us, on the subterranean waters; they are there assembled, as in a mass, in the most secret places of its depth, whence they at times escape to impart fertility to the most barren soils

Thus, when it describes the riches of the country of Canaan, to which a wonderful exuberance of vegetation is promised for the latter times, it represents it not only as abounding in springs and fountains, but particularly in subterranean waters. It seems thereby to anticipate the process of perforation, by means of which the moderns have succeeded in fertilizing the most barren fields and the most sterile countries.

We find, moreover, in the Scriptures, proofs of the extent of the sea, in the early ages; they even contain some succinct details respecting the animals which inhabited them, the greater part of which have preceded the species of the dry and uncovered land. Such facts have required long spaces of time for their operation In truth, the numerous generations buried in the old strata of the globe, and to which the present existing races have succeeded, must have lived during periods of greater or less duration, in order to fulfil the end of their creation. This circumstance of itself proves that the word *iom* used in Genesis, and which is translated *day*, means rather indeterminate epochs, the duration of which it is impossible for us to fix.

While enabling us to understand the extent of the seas, Scripture does not fail to declare to us that God has marked out their limits, and has fixed their boundaries and barriers, which they cannot pass over. In its poetical style it exclaims, "Sea, hitherto shalt thou come, and no further; and here shall thy proud waves be staid."

In other places it points out the depth of the sea, and refers to the greatness of its abysses, maintained by the waters which issue from the bosom of the clouds. The rains also quench the parched lands, and cause the grass of the meadow to spring. With regard to the waters, they are sometimes converted into ice, and become hard as a stone: their solidity thus accidentally gives solidity to the surface of the sea.

It represents the frost as spread over the earth like salt, and making the plants rough like the leaves of thistles. When the cold north wind blows, the water becomes as crystal. The frost rests on the whole mass of waters, and renders them like an impenetrable breastplate.

When the snow falls on the earth, it extends itself over it like a multitude of birds of passage lighting upon it in flocks; it spreads itself like hosts of locusts descending from the clouds. The eye admires the brilliancy of its whiteness; but the mind is alarmed at the inundations it threatens. Finally, when the bad weather ceases, the warm and moist wind becomes felt, and with them the snow and frost disappear. Thus, throughout, and at every step, Scripture indicates to us the influence of the waters diffused through space, and their effects on the earth.

The Bible, in order to give us an idea of the influence of the central heat, does not confine itself to speaking to us of that which it exercised on the waters of the Deluge; it gives us further information, when referring to the interior condition of our planet. In fact, according to it, if the surface of the earth furnishes to man the elements of his nourishment, beneath the solid crust, "The earth is," neverthess, "on fire, and as it were burned up." The greater part of its crust, thus inflamed in the interior, is covered with water on the surface. Above this liquid mass, continents and mountains, which are its most elevated points, have risen up to afford an asylum to man, as well as to terrestrial animals and vegetables.

Who, then, has informed Job that the interior of the earth was filled with such a burning heat? Who has taught him the existence of the central fire, the possibility of which Buffon had conceived before the hypothesis had become a demonstrated fact? We do not reply to this question, on account of the point of view under which we have considered the sacred books.

We have reason to be surprised at thus finding in the Bible physical truths so long misunderstood, or so long unknown; namely, the weight of the air, and the central fire. Notwithstanding the existence of this interior heat, the effects of which it appreciates, scripture does not fail to admit the extent and thickness of the solid crust of the globe, which encloses immense quantities of water concealed in its depths.

The sacred books, it is true. in giving us an idea of these great facts, has not taught us them in the language of natural philosophers. Their language is never that of Copernicus, Newton, Kepler, or Laplace. The reason which has prevented the authors of these admirable books from doing this, is one of the strongest that can be conceived. If they had expressed themselves respecting the scenes of nature, not as these present themselves to our eyes, but according to the notions which philosophers of a future age might form of them, they would certainly not have been understood, even by the most enlightened minds.

Besides, the most advanced language of science is almost in every instance only the language of appearances. The visible and material world is, to a greater extent than is supposed, a scene of illusions and errors. What we call reality is often a mere figure, leading to a more hidden reality, or to an analysis carried a further length. Such an expression, in our mouths, has nothing absolute in it; it is a relative term, which we employ in proportion as we believe that we have ascended a new step in the profound scale of our ignorance.

Above all, it was necessary that scripture should be intelligible to the most vulgar individuals, as well as to the most learned. Let us not, therefore be surprised that it expresses itself according to the habitual and familiar language of science, and that, with it, it speaks of the stars rising, the equinoxes retiring, the planets advancing and doubling their speed, standing still, and moving backwards. We need no longer be surprised that it speaks of the rising and the setting of the sun, since these modes of expression are sanctioned and adopted by the Annuaire of the bureau of longitudes. [The conclusion of this paper will be given next month.]

PRINCIPLES OF ALGEBRA.

CHAPTER XI.

QUADRATIC EQUATIONS.

100. Quadratic Equations are distinguished into *pure* and *adfected.* Such as involve the *square* only of the unknown quantity, are termed *pure quadratics;* and those which involve both the *square* and *simple powers* of the unknown quantity, are called *adfected quadratics.* Thus $x^2 + b = a$ is a *pure quadratic,* and $x^2 + ax = b$, is an *adfected* quadratic.

Every quadratic equation is the product of two simple equations, and must therefore have two *roots* or values of the unknown quantity which it involves. Thus, if the two simple equations $x - a = 0$, and $x + a = 0$ be multiplied together, we have $x^2 - a^2 = 0$, a *pure* quadratic whose *roots* are $+a$ and $-a$: and if the equations $x - a = 0$, and $x + b = 0$, be multiplied together, we have $x^2 - ax + bx = 0$, an *adfected* quadratic whose *roots* are $+a$ and $-b$.

101. *Rule for the Solution of Pure Quadratic Equations.* Transpose and reduce the terms of the equations so that the square of the unknown quantity may stand alone on one side, and known quantities only on the other, and extract the square root of each side.*

1. Given $2x^2 + 6 = 78$ to find the values of x.
Transposing and reducing . . $x^2 = 36$
Extracting the square root . . $x = \sqrt{36} = \pm 6$

Hence, the two values of x are $+6$ and -6; and either of these, if substituted for x in the original equation, will render the two members identical.

2. Given $$2x^2 - \frac{x^2}{3} = \frac{x^2 - 15}{6} + 13$$

Multiplying by 6 . . $12x^2 - 2x^2 = x^2 - 15 + 78$
Reducing . . . . . . $9x^2 = 63$
Dividing by 9 . . . $x^2 = 7$
Extracting $\sqrt{}$ root, $x = \pm\sqrt{7}$

Here, since 7 is not a square number, we can only approximate to the values of x.

3. Given $ax^2 - 5c = bx^2 - 3c + d$
By transposition $(a - b)x^2 = 2c + d$
Dividing by $a-b$. $$x^2 = \frac{2c + d}{a - b}$$
$$\therefore x = \pm\frac{\sqrt{2c + d}}{a - b}$$

102. *On the Solution of Adfected Quadratic Equations.* The most general form under which an adfected quadratic equation can be exhibited is $ax^2 \pm bx = \pm c$; where a,b,c, may be any quantities whatever, *positive* or *negative*, *integral* or *fractional*. Dividing this equation by the coefficient of x^2, it becomes

$$x^2 \pm \frac{b}{a}x = \pm\frac{c}{a}$$

or putting $\frac{b}{a} = p$ and $\frac{c}{a} = q$, for the sake of simplicity, we have
$$x^2 \pm px = \pm q.$$

If to each member of this equation be added the *square of half the coefficient*, p, of the second term, it assumes the form,

$$x^2 \pm px + \left(\frac{p}{2}\right)^2 = \frac{p^2}{4} \pm q$$

That side which contains the unknown quantity is now a complete square, $(x + \frac{1}{2}p)^2$; consequently by extracting the root of each side of this last equation, we have

$$x \pm \frac{p}{2} = \pm\sqrt{\frac{p^2}{4} \pm q}$$

Transposing, we have $$x = \mp\frac{p}{2} \pm \sqrt{\frac{p^2}{4} \pm q}$$
$$= \frac{\mp p \pm \sqrt{p^2 \pm 4q}}{2}$$

103. From the process by which this solution has been obtained, we deduce

Rule I.—1°. Transpose, when necessary, all the known quantities to one side of the equation, and the terms involving the unknown quantity to the other, so that the term containing the square of the unknown quantity may be *positive*.

2°. If the square of the unknown quantity have a coefficient, divide both sides of the equation by it.

3°. Add the square of *half* the coefficient of the simple power of the unknown quantity to each side of the equation, which will make the side containing the unknown quantity a complete square.

4°. Extract the square root from each side of the equation, and prefix the double sign* $\pm$ to the root of the known side; the quadratic equation is now reduced to a simple one, which may be solved in the usual manner.

Example.—Given $2x^2 + 16x - 32 = 8$
Transposing and dividing by 2, $x^2 + 8x = 20$
Adding $(\frac{8}{2})^2$ or 16 to each side, $x^2 + 8x + 16 = 20 + 16$
or, $(x + 4)^2 = 36$
Extracting square root, $x + 4 = \pm 6$; $\therefore x = -4 \pm 6$

Consequently, $$\begin{cases} x = -4 + 6 = +2 \\ x = -4 - 6 = -10 \end{cases}$$

Either of these two values, when substituted for x in the original equation, will render the two members identical.

104. Assuming again the general equation, $ax^2 \pm bx = \pm c$
Multiplying each side by $4a$, then $4a^2x^2 \pm 4abx = \pm 4ac$
Adding b^2 to each side,
$$4a^2x^2 \pm 4abx + b^2 = \pm 4ac + b^2$$
Extracting the $\sqrt{}$ root of each side,
$$2ax \pm b = \pm\sqrt{(\pm 4ac + b^2)}$$
$$\therefore 2ax = \pm\sqrt{(\pm 4ac + b^2)} \mp b$$
$$\text{and } x = \frac{\pm\sqrt{\pm 4ac + b^2} \mp b}{2a}$$

105. From this general process we deduce

Rule II.—Multiply the given equation (when reduced to the form $ax^2 \pm bx = \pm c$) by *four times the coefficient of* x^2, and to each side add *the square of the coefficient of* x, and the first member will be a complete square. Extract the square root from each side, and the result will be a simple equation.

Example.—Given $3x^2 - 5x = 7$, to find the values of x.
Multiplying by 4×3 $36x^2 - 60x = 84$
Adding 5^2 to each side $+ 5^2 = 25$
Complete square $36x^2 - 60x + 5^2 = 109$
or $(6x - 5)^2 = 109$
Extracting $\sqrt{}$ root $6x - 5 = \pm\sqrt{109}$
$\therefore 6x = 5 \pm 10.4019$
$$\text{and } x = \frac{5 \pm 10.4019}{6}$$

Consequently $$\begin{cases} x = \dfrac{5 + 10{\cdot}4019}{6} = 2.56698 \\ x = \dfrac{5 - 10{\cdot}4019}{6} = -.90032 \end{cases}$$

106. Assuming again $ax^2 \pm bx = \pm c$
Multiplying by the series $\frac{1}{a} \quad 1 \quad a$
And changing x to v $v^2 \pm bv = \pm ac$
Completing the square $v^2 \pm bv + \left(\frac{b}{2}\right)^2 = \frac{b^2}{4} \pm ac$, *rule 1st.*
Extracting the $\sqrt{}$ root $v \pm \frac{b}{2} = \pm\sqrt{(\frac{b^2}{4} \pm ac)}$
$$\therefore v = \mp\frac{b}{2} \pm \sqrt{(\frac{b^2}{4} \pm ac)}$$
But $v = ax$, consequently $$x = \frac{\mp\frac{b}{2} \pm \sqrt{(\frac{b^2}{4} \pm ac)}}{a}$$

* This rule may be extended to equations of any degree which involve only one power of the unknown quantity, that is, all equations of the form $ax^n = b$, for dividing each member of this equation by a, it becomes $x^n = \frac{b}{a}$ and extracting the nth root, we have $x = \sqrt[n]{\frac{b}{a}}$

* By using the double sign $\pm$ in the text, the four following forms have been included in the same equation, viz.,

1. $x^2 + px = +q$ where $x = -\frac{p}{2} \pm \sqrt{(\frac{p^2}{4} + q)} = \frac{-p \pm \sqrt{p^2 + 4q}}{2}$
2. $x^2 - px = +q$ . . . $x = +\frac{p}{2} \pm \sqrt{(\frac{p^2}{4} + q)} = \frac{+p \pm \sqrt{p^2 + 4q}}{2}$
3. $x^2 - px = -q$ . . . $x = +\frac{p}{2} \pm \sqrt{(\frac{p^2}{4} - q)} = \frac{+p \pm \sqrt{p^2 - 4q}}{2}$
4. $x^2 + px = -q$ . . . $x = -\frac{p}{2} \pm \sqrt{(\frac{p^2}{4} - q)} = \frac{-p \pm \sqrt{p^2 - 4q}}{2}$

In the *first* and *second* of these forms, the *roots* are both *real*, and one of them is positive and the other negative; but in the *third* and *fourth* forms, the roots may be both real, or both imaginary, that is, *impossible*. This is always the case when $\frac{p^2}{4}$ is less than $-q$.

This process furnishes the data for

RULE III. Multiply the first term by the *reciprocal* of the coefficient of x^2, the second by 1, and the last by the coefficient of x^2, substituting v for x in the resulting equation. The value of v will always be as many times the value of x as the coefficient of x^2 has *units*.

Example. Given $3x^2-2x=65$; to find the values of x.

Multiplying by series	$\frac{1}{3}\quad 1\quad 3$
New equation, with v for x	$v^2-2v=195$
Completing the square	$v^2-2v+1^2=195+1$
Extracting $\sqrt{}$ root	$v-1=\pm\sqrt{196}$
	$\therefore v=1\pm 14=15$ or -13
But $v=3x$, consequently	$x=\frac{15}{3}=5$; and $x=\frac{-13}{3}=-4\frac{1}{3}$

Note.—The second and third terms of the series $\frac{1}{3}$, 1, 3, are found thus: $\frac{1}{3}\times 3=1$, and $1\times 3=3$. When the coefficient of x is an odd number, the coefficient of x^2 may be doubled for a multiplier as in the following:—

Example.—Given	$3x^2+5x=42$
Series $\frac{1}{3}\times 6=2$ and $2\times 6=12$,	$\frac{1}{6}\quad 2\quad 12$
Putting $v=6x$	$v^2+10v=504$
Completing the square	$v^2+10v+5^2=504+25$
Extracting $\sqrt{}$ root	$v+5=\pm\sqrt{529}$
	$\therefore v=-5\pm 23=18$ and -28

But $v=6x$, $\therefore x=\frac{18}{6}=3$, and $x=\frac{-28}{6}=-4\frac{2}{3}$

107. In every adfected quadratic equation, when in the form $x^2\pm px=\pm q$, the *sum* of the roots is equal to the coefficient of the second term with the contrary sign, and their *product* to the second member with its sign also changed. When the equation is in the form $ax^2\pm bx=\pm c$, the sum of the roots is equal to $\frac{b}{a}$ with a contrary sign, and their product to $\frac{c}{a}$ with the contrary sign also. By one or other of these means the accuracy of a solution may always be proved. Thus, in the above example, $\frac{b}{a}=\frac{5}{3}=-4\frac{2}{3}+3$ with the *sign changed.*

ON THE SOLUTION OF QUADRATIC EQUATIONS OF THE FORM

$$x^{2n}\pm px^n=\pm q$$

108. An equation having only *two* powers of the unknown quantity and in which one of the powers is *double* the other, may be solved by the foregoing rules.

For, if in the above equation, we assume $y=x^n$, then $y^2=x^{2n}$, and it then becomes,

$$y^2\pm py=\pm q$$

Where, by the preceding rules, $y=\dfrac{\mp p\pm\sqrt{p^2+4q}}{2}$

But $y=x^n$ $\quad\therefore x^n=\dfrac{\mp p\pm\sqrt{p^2+4q}}{2}$

And extracting the n^{th} root, $\quad x=\sqrt[n]{\dfrac{\mp p\pm\sqrt{p^2+4q}}{2}}$

1. Given $\quad x^4-25x^2=-144$; to find the values of x.

Putting $x^2=y$, and $x^4=y^2$, then $\quad y^2-25y=-144$

Completing the square; $y^2-25y+(12.5)^2=155.25-144$

Extracting $\sqrt{}$ root $\quad y-12.5=\pm\sqrt{12.25}=\pm 3.5$

$\therefore y=12.5\pm 3.5$

Hence $y=16$ and $y=9$

But $x^2=y$, $\therefore x=\sqrt{y}$, hence $x=\pm\sqrt{16}$ and $x=\pm\sqrt{9}$,

$$\therefore \begin{cases} x=+4 \text{ and } -4 \\ x=+3 \text{ and } -3\end{cases}$$

2. Given $\quad x^6-2x^3=48$; to find the values of x.

Let $x^3=y$, then $x^6=y^2$, whence $y^2-2y=48$; $\therefore y=1\pm\sqrt{(1+48)}$

The values of y are therefore 8 and -6

But $y=x^3$, $\therefore x=\sqrt[3]{y}$; hence $x=\sqrt[3]{8}=2$, and $x=\sqrt[3]{-6}$

This equation has six roots, but the remaining four cannot be discovered by this process.

3. Given $\quad x^1-3x^{\frac{1}{2}}=4$; to find the value of x.

Let $x^{\frac{1}{2}}=y$, then $x=y^2$, whence $y^2-3y=4$, $\therefore y=\frac{3}{2}\pm\frac{5}{2}=4$ or -1

But $y=\sqrt{x}$ $\therefore x=4^2=16$ and $x=-1^2=1$

Obs. As this equation involves only the simple power of x, it can only have *one* root. To account then for the two found, it must be observed that the one, viz. 16, belongs to $-x^{\frac{1}{2}}$ and the other, viz., 1, to $+x^{\frac{1}{2}}$. The first verifies the conditions of the original equation, and the second belongs to the equation $x+3x^{\frac{1}{2}}=4$, where the second term is *positive.*

4. Given $\dfrac{\sqrt{(x^2+x+6)}}{3}=\dfrac{18-\frac{4}{3}[\sqrt{(x^2+x+6)}-2]}{\sqrt{(x^2+x+6)}}$

Let $y=\sqrt{(x^2+x+6)}$, then	$\dfrac{y}{3}=\dfrac{18-\frac{4}{3}y+2}{y}$
Multiplying by 3 and y,	$y^2=54-4y+6$
By transposition,	$y^2+4y=60$, whence $y=6$ or -10
Subst. value of y,	$\sqrt{(x^2+x+6)}=6$ or -10
Squaring both sides,	$x^2+x+6=36$ or 100
Transp^g. and comp^g. sq^e.	$(x+\cdot 5)^2=30\cdot 25$, or $=94\cdot 25$
Extracting $\sqrt{}$ root,	$x+\cdot 5=\pm\sqrt{30\cdot 25}$, or $=\pm\sqrt{94\cdot 25}$
	$\therefore x=-\cdot 5\pm 5\cdot 5$, or $=-5\pm 9\cdot 7$

Hence $x=5$, $x=-6$, $x=9\cdot 2$, $x=-10\cdot 2$

These equations may be solved by the common rules without the substitution of y, which has been done in the above examples for the sake of perspicuity alone.

ON THE SOLUTION OF QUADRATIC EQUATIONS CONTAINING TWO UNKNOWN QUANTITIES.

108. An equation containing two unknown quantities is said to be of the *second degree* when it involves terms in which the *sum* of the exponents of the unknown quantities is equal to 2; but when one, or both of these quantities are found in a quadratic form, a solution, by the preceding rules, can be effected only in particular cases.

CASE I. When one of the given equations is of the first degree.

RULE.—Find a value of one of the unknown quantities in terms of the other from the simple equation, and substitute that value instead of it, in the other equation. The resulting equation will be a quadratic, solvable by the rules already established.

Given $\begin{cases} x+3y=10\ \dots (1) \\ 2x^2+3xy-y^2=52\ \dots (2)\end{cases}$ to find x and y.

From equation (1) we find $x=10-3y$, and substituting this expression for x in equation (2), it becomes

$$2(10-3y)^2+3y(10-3y)-y^2=52$$

or $\quad 200-120y+18y^2+30y-9y^2-y^2=52$

Reduced . . . . $4y^2-45y=-74$

Multiplying by the series $\quad\frac{1}{4}\quad 1\quad 4$

$v^2-45v=-296$, *rule 3d*

Completing the square $\quad\left(v-\dfrac{45}{2}\right)^2=\dfrac{2025}{4}-296$

Extracting $\sqrt{}$ root $\quad v-\dfrac{45}{2}=\pm\sqrt{\dfrac{2025-1184}{4}}$

$\therefore v=\dfrac{45}{2}\pm\dfrac{29}{2}$

But $y=\dfrac{v}{4}$, consequently $\quad y=\dfrac{45}{8}\pm\dfrac{29}{8}=2$ or $9\frac{1}{4}$

Substituting these values for y in the equation, $x=10-3y$, we have.

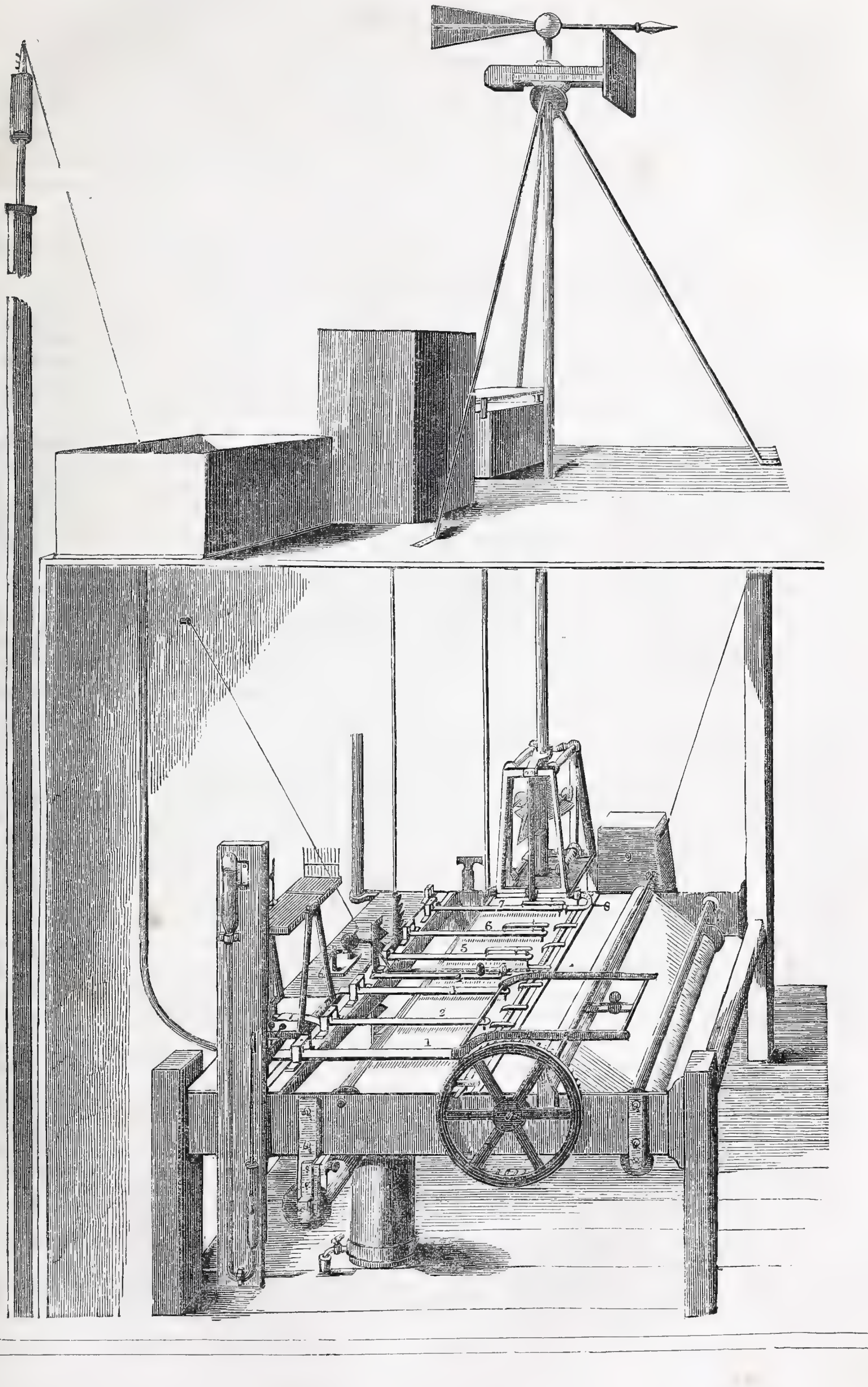
$$x=10-3\times 2=4 \text{ and } x=10-3\times 9\tfrac{1}{4}=-17\tfrac{3}{4}$$

Hence the corresponding values which verify the given conditions are

$$\begin{rcases} x=4 \\ y=2\end{rcases} \text{ and } \begin{cases} x=-17\frac{3}{4} \\ y=+\ 9\frac{1}{4}\end{cases}$$

DOLLOND'S SELF-REGISTERING ATMOSPHERIC RECORDER.

SELF-REGISTERING instruments, which move equally by clockwork or otherwise, and are made subservient to the registration of natural phenomena, are of the highest importance, and particularly so in meteorological investigations, where the changes of every element of research are perpetual, and those which



accrue during the night are of equal importance to those happening during the day.

An admirable specimen of such apparatus, invented by Mr. George Dollond, of St. Paul's Churchyard, London, appeared in the philosophical department of the Great Exhibition of 1851. This instrument self-registers simultaneously, on paper, the varying pressures of the atmosphere, the changes of the temperature of air and evaporation, and those of the electrical states of the atmosphere, the fall of rain, the amount of water evaporated from a surface of water, and the force and direction of the wind.

The atmospheric recorder will correctly register the slightest change which takes place during any period of time according to the length of the paper.

The apparatus is composed of a frame of about two feet by three feet six inches, firmly supported upon four pillars, the sides of the frame being strongly bolted together at two feet from each other. At one-fourth from each end of the frame, a roller of one foot in circumference is introduced. To one of these rollers an eight-day clock is attached, which moves it round once in twenty-four hours. At half right angles above that roller is another of the same dimensions, so arranged as to press upon it equally throughout its length. The last-mentioned roller is for the purpose of keeping the paper in contact with the driving or clock roller.

The apparatus is represented in the annexed engraving, fig. 1. The roller at the other end of the frame acts as a rest for carrying the paper to be registered to a platform in the middle of the frame, which has its face in the same plane as the upper sides of the rollers.

Near the end of the frame, which is placed towards the north, is a strong bar, upon which all the fulcrums of the indicators or markers are placed, from which arms of one foot in length, having spring points at their ends for the barometer, thermometer, and hygrometer, are struck into the paper every half hour by a falling lever, or frame. For the electrometer, rain, evaporator, force and direction of the wind, ever-pointed pencils are used, which make a continuous mark upon the paper, with a weight pressing upon them so as to render the marks perfectly distinct without interrupting their proper motion.

Beyond the fulcrums there are continuations of the arms of the indicators, to which are applied, by various contrivances, the powers which give motion to the indicators, in those proportions which are required by the scales of the eight instruments which mark the various changes of the atmosphere. Each indicator has its proper scale placed near to the line of the registering points and pencils, so that the last indentures or marks on the paper may be compared with their respective scales, and the time referred to at which the indication took place.

There are also a set of liners which separate each department, and form zeros or boundary lines throughout the whole run of the paper, commencing at the point or place of the indicators, from which any movement or hygrometric change of the paper may be referred to for correction.

On each side of the frame there is a marker for time; these are governed by a wheel attached to the clock roller, which, by a lever and inclined planes, are made to register the time correctly at every half-hour, and sixth hour more strongly for the convenience of counting. The advantage of thus marking the time on both the edges of the paper is very considerable; for when the paper is taken off, or at any time examined, a line drawn across, corresponding with the opposite marks, will show the correct period at which any change in the atmosphere took place. Having described the general formation of the apparatus, it will be requisite to give a detailed account of those parts which are more immediately acted upon by the atmosphere, and the manner in which they are made to register the results.

The barometer is upon the siphon principle of a large bore. Upon the surface of the mercury, in the shortest leg, is placed a float very accurately counterpoised, leaving only sufficient weight to compel it to follow the mercury, and correctly adjusted to that part of the apparatus which moves the indicator, when the pressure of the atmosphere is at 30 inches. The connection of the float with the indicator is so arranged as to give a scale of three to one, which has been found to maintain the register in the most perfect manner, under comparison with an excellent instrument of the best construction.

The thermometrical arrangement consists of ten mercurial thermometers of a peculiar form. These are suspended upon an extremely delicate and accurate balance, by which a correct register of all the various changes in this climate have been found to agree with the best thermometers of the usual construction. They are placed at the north end of the frame, and are screened from the effects of the wind and rain by perforated plates of zinc.

The hygrometer consists of a slip of mahogany cut across the grain. This was placed in a cylinder filled with water, and suspended from the upper end, with a weight of two pounds at the other end, until it was found by repeated examination to be completely saturated, and no longer to increase in length. The length was then referred to an accurate scale, and the slip of mahogany placed by the side of the pipe of a stove, under the same suspension and weight, until its shortest length was obtained. The difference of the two results being carefully taken, the scale was formed accordingly. It is placed in a tube, open at both ends for a free passage of air, outside the observatory. It is suspended and weighted as before, with full power to act upon the arm of the indicator, quite free from the action of the sun or rain, and is found to be extremely active and firm in its operation, showing upon an open scale every hundredth of its extremes in dryness and moisture.*

The next part of the arrangement to be described is the electrometer for thunder-storms and electric changes. This is constructed by placing a well-insulated conductor upon the highest convenient place, from which a wire is brought down to an insulation on the top of the observatory, and from thence to a standard through another insulation to a metal disc, between which and a spring there is a moveable disc attached to a glass or insulating arm, for the purpose of connecting it with an accurate support, upon which it can move with the greatest facility. In connection with this arm and disc, there is a pencil carried forward to the line of indication. The spring before stated is fixed to a standard at about three inches from the first disc; to this a wire is attached and carried into the earth. By this arrangement, the electricity put in motion by a thunder-cloud is received and registered. The effect of this arrangement during a thunder-storm is extremely interesting. When a cloud charged with the electric fluid comes within the range of the conductor, the moveable disc begins slowly to pass from the first disc to the spring, discharging each time a proportion of the electricity, and increasing in rapidity of motion until the discharge of the cloud by lightning takes place. It then falls back to the first disc, and remains perfectly quiet until the next electric cloud approaches. If, in the interim, a cloud charged with rain only should descend or pass over, no movement of the disc takes place.

The pluviometer, or that part of the apparatus which is arranged for registering the quantity of rain that falls, is formed in the following manner:—On the top of the observatory there is a receiver of one foot square, clear from all surrounding matter that might interfere with the direct fall of the rain upon its surface. From this receiver a pipe conducts the rain into another receiver inside the observatory, directly under the registering apparatus; in this there is an air-float, connected with a set of inclined planes, each inclined plane being equal to one inch of rain. These inclined planes, as they pass up, move the indicator across the destined proportion of the paper; showing, as it proceeds, the result of each drop to the hundredth part of an inch in superficies, and continues to advance until it arrives at one inch. It is then instantly discharged, and returns to the zero of the scale, or commencement of another inch. The internal receiver is calculated to contain six inches of rain—a quantity that seldom falls in this island during one month. The register will show when it is

* This method of constructing a hygrometer was recommended by Henry Lawson, Esq., F.R.S., from one in his possession, made for and used by the late Dr. Benjamin Franklin, which now performs with precision, although made more than half a century ago.

nearly full. The water can then be drawn off without the slightest inconvenience, and the float be readjusted to the zero of the first inch.

The evaporator, 10, is an open cube of one foot square, which is supplied with water from the larger vessel, and is connected with the cube by a pipe underneath the two vessels, 10-10. From that connection, the indicator of evaporation is carried to the marker or arm, 6, of the registering paper, and is supported by a float from the surface of the water in the larger vessel. The cube or evaporator is covered by a plate of glass at an angle of sufficient elevation to prevent rain from falling into it, but not so close as to resist the air from freely acting upon the surface of the water. When the water is exhausted, it may be refilled from the pump in the observatory.

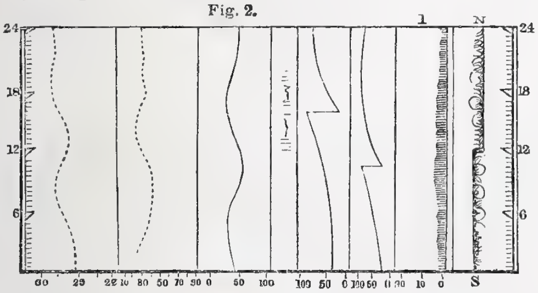
The power or force of the wind is registered by a combination of suspended weights, acted upon by inclined planes or edges, in connection with a board of one foot square to receive the impression; this board is kept in opposition to the direction of the wind by a powerful vane, its motion being as free from friction as possible, every part being correctly counterpoised. When the board is acted upon by the wind, it raises the suspended weights by a chain passing over a pulley in a line with the direction of the wind, and well secured from the weather. The suspended weights in connection with an inclined lever carry the pencil of indication along the scale, which registers the weight lifted in ozs. and lbs. avoirdupois; the scale having been found, by repeated trials, to be correctly equal to the weights recorded upon it.

The direction of the wind is also registered at the same time by another pencil, which marks the course upon the paper, throughout the whole circle of the horizon, or that proportion through which it passes.

For the convenience of placing upon the instrument the paper to be registered, there is a roller, with a flange at each end, to keep it from being deranged as it is unrolled, for which proper receptacles are provided for the pivots underneath the frame, and parallel to the rollers above.

Fig. 2 represents one day's work of this instrument.

Fig. 2.



The end of the paper is carried from this roller over the one above, at the north end of the frame, and conducted under the indicators, and over the platform to the driving and pressing rollers; it is then to be drawn forward until it reaches a similar roller to that on which it was first rolled, also underneath the frame; to this roller, it is then to be fastened by springs prepared for that purpose. This roller has attached to one of its pivots a worm, upon which a weight is wound up; which weight is equal to the power requisite to wind up the paper as it comes from the driving roller, leaving a space between them, which gives the observer an opportunity of seeing what has been registered during the last twenty-four hours.

For the purpose of reading off the register when removed from the apparatus, there are a set of scales in combination, corresponding correctly with those upon the instrument.

The whole may be placed in a room six feet square, having an opening to the north for the convenience of placing the thermometer out of the range of the sun's rays, and the better for the action of the hygrometer. For the convenience of the lightning conductor and vane, an upper room would be preferable.

Lawson's meteorological thermometer stand:—This apparatus consists of a frame of white deal boards, and can be formed or constructed by any carpenter. It is made of an oblong trunk 12 inches by 8 inches outside measure; to the opposite sides of which trunk are nailed boards, at the distance of three-quarters of an inch, and projecting about six inches from the trunk towards the north. Outside of these are nailed other thin boards, full half an inch distant, and projecting about four inches beyond the last-mentioned boards, also towards the north. These sides or shades being multiple, prevent the sun from heating the interior of the stand where the thermometers are placed. The top, or pent board, is made double, and the boards are placed at full three-quarters of an inch distant from each other, and come so forward as to overhang, by a full inch, the night index thermometer, placed immediately beneath, for the purpose of preventing rain or dew from falling perpendicularly upon the bulb of the thermometer. The legs of the stand are merely the continuation of the sides of the trunk. The board is loaded, or the feet fixed to the ground, to sustain the force of the wind. The interior is blackened to prevent strong reflections of light.

On the north side of the stand is an index thermometer, to give the greatest heat of the air in the shade each day; and an index spirit thermometer, to give the greatest cold of the night. There are also two thermometers, with finely-graduated scales, which are called the wet and dry bulb thermometer, to show the power of air to evaporate water, and a conical vase of considerable size to hold water for the wet bulb thermometer; it is of glass, for the purpose of seeing when it requires refilling, and conical, to prevent its being broken by frost.

On the south side of the stand is an index mercurial thermometer, with a black bulb, to give the greatest solar heat of each day. On this side is a rain-gauge, which conveys the rain into a bottle enclosed within the trunk. From the bottle, the water is to be poured into gauge tubes, provided for the purpose of showing the quantity of rain that has fallen.

The meteorological thermometer stand, as above arranged, will be found to possess the following advantages. It can be placed in any eligible spot that may suit the convenience of its owner. Its four sides can, and must, be placed to face the cardinal points, commanding therefore a true north and south aspect. It can be visited on every side, and be free from all surrounding objects. The instruments or thermometers used, can be read off with the greatest facility; and the whole will be at a known distance from the ground. Those instruments placed on the south face, will have the meridian sun; and those on the north face, will be always in the shade, in consequence of the projecting wings. It can be employed by any meteorologist, wherever residing. It is of a determinate form, height, and size. It is not costly, but firm; and can be placed on any open spot that may be thought eligible for its use. The instruments may be read off with the greatest promptitude, so as to prevent or reduce errors arising from the person of the observer being too long in the vicinity of the thermometers. By the general adoption of this stand, instruments placed upon it will all be used or observed under similar circumstances, and deductions therefrom be more correctly drawn than at present. It follows, therefore, that observations made by individuals wherever residing, either in Europe, Asia, Africa, or America, if drawn from instruments thus similarly placed, can be compared one with the other with far less chance of error than has hitherto been the case.

In using instruments, a certain adroitness is necessary; but a little practice will render the use of the thermometer stand in every respect easy. The thermometers used should have their bulbs perfectly free from the scales, whether of metal or wood, and that a space of at least half an inch be interposed between the bulb of each thermometer and its scale, and place whereon it is fixed; as in some states of the atmosphere, great errors will be the consequence of their touching any surrounding body. The metallic indices in the tubes of registering thermometers, are apt to tarnish and cease to slide with the required ease, which may be prevented by passing them up and down the tube, half a dozen times, at every notation of the thermometer. When the thermometers are put by and out of use, the indexes should be moved to the end of the tube furthest from the bulb, and left there.

MACHINE FOR SHELLING GRAIN.

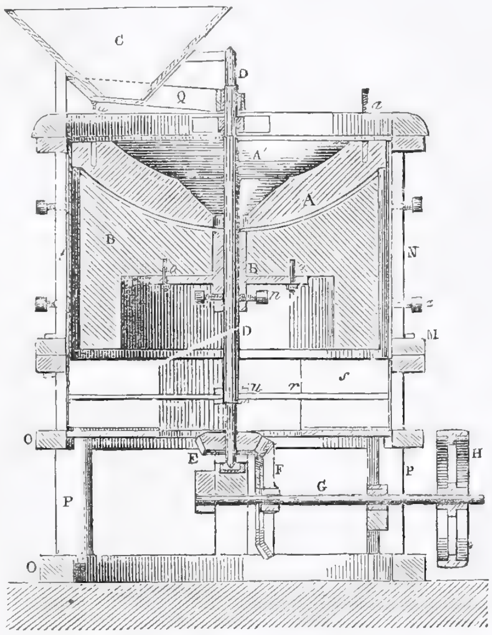
BY M. LACHAMBRE, OF CIRCOURT (VOSGES).

This machine, represented in vertical section in the annexed figure, consists of two millstones, of that kind of stone known by the name of *arkose*. The form of these millstones is that of two spherical and concentric basins.

The upper millstone, A, is immoveable, and is fixed to the flooring above by means of four screws, *a*, the heads of which are sunk in the stone, and which, passing through moveable nuts, serve to regulate its distance from the lower millstone, B.

To diminish the weight of the stone, A, the inventor has hollowed out in its upper part a considerable cavity, A′, forming in the middle a funnel or cone, terminated by a cylindrical part, and intended to afford a passage to the grain falling from a hopper, C, on the concave surface of the lower stone.

This inferior stone, B, which is hollow in its upper surface,



is fitted at its centre with a cylindrical cast-iron collar, L, drilled perfectly true, and fixed to the vertical shaft, D, by means of two steel screws, *n*, and made fast to the stone by the four screws, *o*. To lighten the stone it is hollowed out below.

The vertical shaft, D, of wrought-iron, is fitted at its lower part, about six inches from the under surface of the moveable stone, B, with a collar, *u*, made of wrought-iron, and turned; this collar is furnished with four arms, *r*, terminating in wings of sheet-iron, which partake of the rotatory movement of the vertical shaft, act like fanners, and drive the dust from the grain. Beneath this winnowing apparatus, the shaft is armed with a conical pinion, E, gearing with the bevil-wheel, F, which is mounted on the horizontal shaft, G; and this last transmits to the whole of the machinery the movement communicated to it through the pulley, H.

The two millstones are encased, from top to bottom, in a cylindrical wooden frame, lined internally with sheet-iron, having a rasped surface. This frame is divided into two parts—the upper portion being of the same height as the millstones, and formed of two crown-pieces, M, and six supports, N; the lower consisting of three crown-pieces, *o*, and six supports, P.

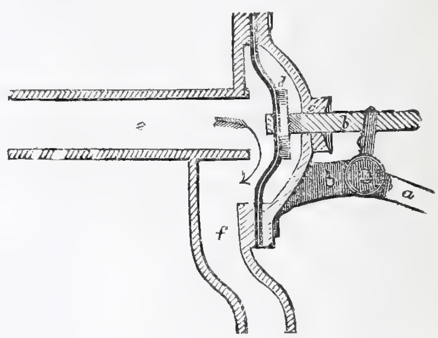
The grain is poured by the usual means into the hopper, C, which is furnished at its lower part with a riddle, Q; from the riddle the grain passes through the funnel-shaped space of the upper millstone, and thence it falls upon the hollow portion of the lower millstone, which partakes in the rotatory motion of the vertical shaft—this making, on an average, two hundred turns per minute. In consequence of this rotatory movement, the grain, after being well worked between the two concentric surfaces, rises again along the hollow face of the moveable stone, and passes out at its circumference to be worked anew in the space left between the exterior of the turning millstone and the rasp. This space, which has a height of about two feet, may be increased or diminished in width by the working of twelve horizontal screws, Z, which pass through the wooden supports, and abut against two hoops of iron encircling the rasp in its whole circumference. At the ends of each of these hoops is a screw, intended to diminish at pleasure the diameter of the hoops and of the rasp.

On arriving at the lower part of the stone, the grain escapes by a suitable opening made in the exterior framework, so as to pass before the blades of the fanners, by which it is cleared from its dust and other volatile impurities.

IMPROVEMENTS IN STOP-COCKS.

The accompanying engravings represent two modifications of an ingenious improvement in stop-cocks or valves lately introduced by Messrs. Lambert and Richards of Blackfriars, London. The many inconveniences which beset the common conical plugged stop-cock are here overcome, by substituting for it a stop or diaphragm of some elastic material, as vulcanized

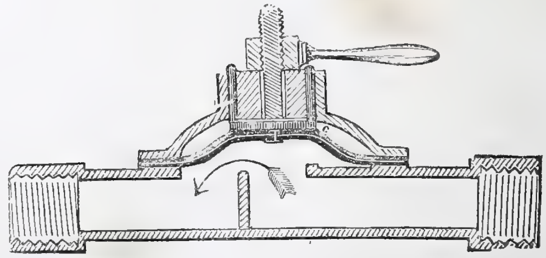
Fig. 1.



caoutchouc, laid on canvas, or other flexible substance. Fig. 1 exhibits the arrangement as applied to a cistern ball-cock.

The arm to which the ball or float, used for giving motion to the valve, is attached, is seen at *a*; it works on a centre connected to the cap of the valve, its upper end being bent, and passed through a slot in the spindle, *b*. The latter works through a gland in the cap at *c*, its inner end being attached to the centre of the flexible diaphragm, *d*. This diaphragm is retained in its place by the flange of the cap, which is bolted

Fig. 2.



upon it to the face of the supply pipe. In our engraving, the valve is supposed to be open to allow the water from the supply pipe, *e*, to pass down through the pipe, *f*, to the receptacle below, as indicated by the arrows. Upon the rising of the float from the continued supply of water, the spindle, *b*, will be pressed inwards, carrying with it the diaphragm, *d*, until

the latter is forced close down on the face of the pipe, *e*, so as to prevent the further flow of water. In this contrivance there is no actual friction between the face and the valve, so that the only wear to which these parts are subjected results from the flow of the water. Fig. 2 is an example of the principle applied to gas mains, as a stop-valve for gas. Here the flow is supposed to be from right to left, as indicated by the arrow. The spindle for moving the stop is elevated and depressed by a nut on the lever handle—one side of the face for receiving the pressure of the stop, being formed by a partition cast on the bottom of the main.

GEOGRAPHY.

CHAPTER VIII.

SUBDIVISIONS OF EUROPE—COMPREHENDING A BRIEF SKETCH OF ITS DIFFERENT KINGDOMS.

THE BRITISH EMPIRE.—II. SCOTLAND.—(CONTINUED.)

9. ISLANDS OF SCOTLAND.—The islands of Scotland form nearly a sixth part of its area, and are, therefore, one of its most characteristic features; their importance, however, is by no means commensurate with their number or magnitude, being, for the most part, hilly, rugged, and sterile, and many of them bare, weather-beaten rocks.

On the *east coast* there are no islands, with the exception of a few small and unimportant ones in the frith of Forth, the chief of which are—

Inchcolm—containing the ruins of a monastery, opposite Aberdour, in Fifeshire. Small.

Inchkeith—on which is an elegant lighthouse, opposite Leith. Small.

The Isle of May—at the entrance of the frith; has a lighthouse.

The Bass Rock—almost inaccessible; formerly a state-prison.

The Bell Rock—12 miles south-east of Arbroath, covered at high water; has a stupendous lighthouse, 115 feet high, with reflectors, erected in 1811.

On the *west coast* the islands may be conveniently arranged into three great groups.

(1.) *The Islands in the Frith of Clyde.*

Bute—18 miles long, 5 broad; except towards the north, where it is high and rugged, it is distinguished for picturesque beauty and mild climate. Pop. 9,351.

Arran—large oval island, 18 miles long, 12 broad; noted for its mountainous aspect and the remarkable geological formation of its rocks. Pop. 5,857.

The two Cumbrays.—two small islands on the Ayrshire coast; on the west side of Little Cumbray there is a lighthouse. Pop. 1,275.

Ailsa Craig—a rocky islet off the coast of Ayr, 2 miles in circumference, and 1,098 feet high, pastured by a number of goats, and a favourite breeding-place for sea-fowl.

(2.) *The Islands of the Inner Hebrides, lying near the mainland.*

Belonging to Inverness-shire.

SKYE—one of the largest of the Western Isles, 46 miles long by 25 broad, remarkable for its lofty cliffs and spar cave. Pop. 21,528.

Raasay—a small hilly island, chiefly used for pasture-land; it lies between Skye and the mainland of Ross-shire.

Rum—a small island, extremely bleak and barren, with little cultivation, lying to the south of Skye.

Eigg—a very small island, principally pasture-land; is of a diversified aspect, and bounded by rugged rocks.

Belonging to Argyleshire.

Mull—25 miles long by 20 broad; a very stormy, rainy, and dreary island. The chief produce is black cattle and sheep; its agricultural produce is not sufficient to support the population, which amounts to 7,485.

Isla—south-west of Jura, is 24 miles long, 18 broad; in general, mountainous, but has much level cultivated land; famed for its whisky, its cattle, and horses. Pop. 12,334.

Jura—north-east of Isla; much smaller; a great portion of it is rugged and barren. Noted for three conical mountains, called the Paps of Jura, the highest of which is 2,470 feet. Pop. 1,064.

Iona or *Icolmkill*—a very small island, west of Mull, of a rugged and mountainous aspect; famed as the retreat of learning and religion at a very early age. St. Columba founded a monastery here in 573, the ruins of which still remain. Here were interred the remains of 48 Scottish kings, 4 Irish kings, and 8 Norwegian kings. In 1561, the whole of the ecclesiastical buildings were demolished by the reckless *reformers*. Pop. 604.

Staffa—a small island on the west coast of Mull, celebrated for its basaltic columns and caverns. The famous cave of Fingal is 66 feet high, 42 wide, and 227 feet long, presenting a most beautiful and magnificent scene. "Staffa," says Dr Garnett, "is undoubtedly the greatest natural curiosity of Europe, if not of the world."

Tiree—a small island, but its surface is flat and fertile, and is one of the most valuable of the Hebrides. Noted also for its beautiful marble. Pop. 3,709.

(4.) *The Outer Hebrides, forming a high range* 140 *miles long.*

The *Hebrides* or *Western Isles* (anciently *Ebudes*), is a range of islands 200 in number, of which only 70 are inhabited. The united population of the whole in 1851 was 89,677. They are all decidedly rugged and barren, and in many places covered with extensive tracts of moor and moss. The principal islands in the range are the following:—

Lewis and *Harris*—which form together one long island, is by far the largest. *Lewis* is in some parts very hilly; in others, low, mossy, or covered with lakes; the chief arable land is on the sea-shore, or in the vicinity of Stornoway, the only town of the Outer Hebrides. The soil and the climate combine to keep Lewis in a state of desolate wildness; the inhabitants were lately in a wretched state, living in hovels like *pigsties*; this state of matters, however, is undergoing a great improvement, by the enterprise and benevolence of the spirited proprietor, Sir J. Matheson. *Harris* is the name of the southern portion of this long island, and is a mountainous, steep, wild, and uncultivated waste, with the exception of a few small patches here and there. The inhabitants are in the most primitive condition; and, in short, nothing but an unaccountable attachment to the soil of one's birth could induce people to live in Harris.

North Uist, Benbecula, South Uist, Barra, &c., present nearly similar features, and with the exception of *Barra*, which is wonderfully fertile, are almost all covered with rocks, lakes, or bogs, producing a very scanty vegetation, and presenting a wild and dreary appearance, most of them being totally unfit for the abode of man.

On the *north coast* of Scotland are two distinct groups, viz.—

(1.) *The Orkney Islands* (anciently *Orcades*), a group of islands, 67 in number—of which 29 are inhabited, the rest tolerably fertile—separated from the mainland by the Pentland Frith, containing a population of 30,189, and the whole occupying an area of 281,600 acres. The Orkneys are destitute of trees, but their appearance is favourable and inviting; some have rocky and precipitous shores, rising into low rounded hills, covered with heath; others are low and flat, with sandy shores. The island of Sanda is the most fertile, and is hence called the granary of the Orkneys. The climate is wet rather than cold; frost rarely continues for more than two or three days in succession, and the harbours are open all the year round.

(2.) *The Shetland or Zetland Isles*, supposed to be the *Ultima Thule* of the ancients, are a group of islands, 48 miles north-east of the Orkneys. They are upwards of 100 in number, only 32 of which are inhabited, the others being either small verdant isles, on which cattle and sheep are pastured, or sterile masses of rock.

The largest of the Shetland isles is called the Mainland, and is 55 miles long, varying in breadth from 3 to 10, and, in one part, to 24 miles. Yell is the second, and Unst the third largest island; the others are all small.

The Shetland islands present from the sea a heavy and unvarying line of abrupt coast; their surface is very rugged and wild, often presenting scenes of peculiar desolation and sterility. There are a few tracts of cultivated and fertile land near the sea-coasts, but, from the inhabitants directing their attention almost exclusively to fishing, the agriculture is rude and little attended to. Lerwick, the only town in Shetland, has an irregular and confused appearance, but is a bustling and interesting town, with a thriving and industrious population of 2,904. Shetland is famous for its extensive cod fishery, its breed of small ponies, and its fine wool.

From the high latitude of these islands, the daylight at midsummer never totally disappears; the smallest print can be read at midnight; while in winter the nights are proportionally long and dreary, and in December the sun is not above the horizon more than 5 hours and 20 minutes.

10. Extent and Divisions of Scotland.—Its length, from Cape Wrath to the Mull of Galloway, is about 280 miles, and its breadth, from Buchan-ness, in Aberdeenshire, to the most westerly point in Ross-shire, is nearly 150 miles. Its *area* is estimated at 31,324 square miles, while the following is a summary of the census from 1801 to 1851 inclusive :—

1801.	1811.	1821.	1831.	1841.	1851.
1,599,068	1,805,688	2,092,456	2,365,114	2,628,957	2,888,742

Scotland is divided into thirty-three counties or shires, which, with their area, population, and distinguishing features, are as follow :—

Eleven Northern Counties.

Name.	Area in Sq. Miles.	Population.	Distinguishing Features.
Orkney and Shetland	1,320	62,533	Formed by the islands bearing these names.
Caithness	618	38,709	Mountainous; great herring fishery on its coast.
Sutherland	1,903	25,793	Mountainous.
Ross and Cromarty	2,424	82,707	Do., with some fertile tracts.
Inverness	4,600	12,793	Do. do.
Nairn	200	9,956	Small but fertile county.
Elgin or Moray	840	38,959	Except the upper mountainous districts, fertile.
Banff	647	54,171	Same as last.
Aberdeen	1,980	212,032	Comprises the districts of Mar, Garioch, Formartin, and Buchan, the first of which is mountainous, the others fertile.
Kincardine or Mearns	360	34,598	Surface varied.

Nine Middle Counties.

Name.	Area in Sq. Miles.	Population.	Distinguishing Features.
Forfar or Angus	840	191.264	Fertile. Noted for its breed of cattle.
Perth	2,588	138,660	Comprising the districts of Monteith, Breadalbane, Rannoch, Athole, Strathearn, Stormount, Balquhidder, and the Carse of Gowrie; the last noted for its fertility.
Fife	504	153,546	Beautiful and fertile county.
Kinross	70	8,924	Small inland county, west of Fife.
Clackmannan	52	22,951	Very small, on north side of the Forth.
Stirling	489	86,237	Fertile; lying between the friths of Forth and Clyde.
Dumbarton	260	45,103	In west of Scotland; varied surface.
Argyle	3,956	89,298	Much indented by arms of the sea.
Bute	165	16,600	Comprising the islands of Bute, Arran, Inchmarnoch, and the Cumbrays.

Thirteen Southern Counties.

Name.	Area in Sq. Miles.	Population.	Distinguishing Features.
Haddington, or East Lothian	224	36,386	Very fertile. Agriculture in great perfection.
Edinburgh, or Mid Lothian	354	259,435	Metropolitan county. Very fertile and well cultivated.
Linlithgow, or West Lothian	112	30,135	Fertile. Lies along the south side of the Frith of Forth.
Berwick, or Merse	476	36,297	Fertile and well cultivated. Lies in the south-east of Scotland.
Roxburgh	227	51,642	A border county. Fertile.
Selkirk	264	9,809	Pastoral. In south of Scotland.
Peebles	388	10,738	Called Tweeddale. Pastoral. Lying along both sides of upper course of the Tweed.
Lanark or Clydesdale	926	530,169	Divided into Upper, Middle, and Lower Wards. One of the most important counties in Scotland.
Renfrew	227	161.091	Lies along the Clyde. Great seat of trade and manufactures.
Ayrshire	1,600	189,851	Lies on south-west coast: comprises the districts of Carrick, Kyle, and Cunningham; noted for its agriculture, cattle, and dairies.
Dumfries	1,016	78,123	Comprises the districts of Eskdale, Annandale, and Nithsdale; a fertile and important county.
Kirkcudbright	882	43,121	Maritime county, on Solway Frith.
Wigton	459	43,389	Maritime county, in south-west point of Scotland.

II.—Principal Towns.

Name.	Situation.	Population.	Remarks.
Edinburgh	Near south shore of Frith of Forth	160,302	Metropolis of Scotland; seat of the courts of law, and of a long-celebrated university; is a beautiful city. The New Town, built within the last seventy years, has, perhaps, no equal in Europe.
Glasgow	In Lanarkshire, on the Clyde	329,097	The chief manufacturing and commercial city in Scotland. It has most extensive cotton and other manufactures; carries on a great trade with America and the West Indies; has a flourishing university; in short, it is the first city in Scotland, for population, commerce, and wealth.
Dundee	In Forfarshire, on the Frith of Tay	79,931	Is a large and commodious seaport, carries on a great trade in shipping, and has extensine linen manufactures.
Aberdeen	Capital of county	71,973	A seaport, with extensive trade and manufactures. It is built of granite, which has a neat and clean appearance; is the seat of two universities, about a mile apart; capital of the north of Scotland.
Paisley	In Renfrewshire	47,952	Is a great seat of the manufacture of silk and cotton fancy goods.
Greenock	Do., at the mouth of the Clyde	36,689	The principal seaport of Scotland; has an extensive trade, and is noted as being the birthplace of the celebrated James Watt, in 1736.
Leith	On Frith of Forth	30,919	May be considered the seaport of Edinburgh, from which it is but $1\frac{1}{2}$ miles distant; has an important trade.
Perth	On the Tay	23,835	An ancient city, delightfully situated, and surrounded by beautiful scenery.
Kilmarnock	Ayrshire	21.443	The seat of considerable manufactures.
Ayr	Ayrshire	17,624	Noted for its associations with the poet Burns.
Arbroath	Seaport in Forfarshire	16,986	Has a considerable trade. Here are the ruins of an ancient abbey.
Montrose	In Forfarshire, at the mouth of the South Esk	15,238	Flourishing seaport.
Airdrie	In Lanarkshire	14,435	Thriving town. Great coal and iron works in neighbourhood.
Dumfries	On Nith, 9 miles from the Solway Frith	13,166	A handsome town.
Dunfermline	West of Fifeshire	13,836	Noted for the ruins of its ancient abbey and royal palace, and for its manufactures.

Name.	Situation.	Population.	Remarks.
Stirling	On the Forth	12,837	Commands a noble prospect of the Forth. Has a celebrated ancient castle. It was a favourite residence of the Scottish kings.
Inverness	Near where the river Ness joins the Moray Frith	12,793	Capital of the Highlands; delightfully situated five miles north-east of the moor where the battle of Culloden was fought in 1746.
Kirkcaldy	In Fifeshire, on Frith of Forth	10,475	Seaport. Carries on considerable trade.
Hamilton	In Lanarkshire, near junction of Avon and Clyde	19,630	Noted for the Duke of Hamilton's splendid palaces in vicinity.
Forfar	In Forfarshire, in valley of Strathmore	9,311	In centre of a fine agricultural country.
Falkirk	In Stirlingshire	8,752	Noted for its large cattle-markets, called *trysts*.
Girvan	In Ayrshire	7,319	A seaport. Carries on a considerable trade.
Peterhead	In Aberdeenshire	7,298	A seaport. Has a fine harbour, and carries on a large trade in fisheries.
Campbelton	In Argyleshire	6,880	A seaport, at the head of a beautiful bay.
Wick	In Caithness-shire	6,722	A seaport. Seat of a great herring fishery.
Hawick	In Roxburghshire	6,683	A thriving manufacturing town.
Brechin	In Forfarshire	6,637	A manufacturing town; once an episcopal see.
Elgin	In Morayshire, 5 miles from sea	6,337	Noted for its ancient cathedral, one of the most magnificent ruins in Scotland.
Banff	In Banffshire, at mouth of Deveron	6,000	A seaport.
Galashiels	In Selkirkshire, on the Gala	5,918	Noted for its woollen manufactories.
Dumbarton	In Dumbartonshire, on Clyde	5,445	Noted for its ancient and very strong castle, on a precipitous rock.
St. Andrews	In Fifeshire	5,107	A very ancient city, and the seat of a university. It was once the ecclesiastical capital of Scotland. Noted also for the ruins of its ancient castle, chapel of St. Regulus, and noble cathedral.
Dalkeith	6 miles south from Edinburgh	5,086	Beautiful little town. Dalkeith Palace, the seat of the Duke of Buccleuch, is in the vicinity.
Lanark	In Lanarkshire	5,008	Near this are the celebrated falls of the Clyde.
Kelso	In Roxburghshire, at junction of Tweed and Teviot	4,783	Beautifully situated town. Noted for the ruins of a magnificent abbey.
Linlithgow	In Linlithgowshire	4,213	Noted for the ruins of the noble palace in which Queen Mary was born.
Bannockburn	In Stirlingshire	2,627	Thriving manufacturing village. Noted as the scene of the battle of Bannockburn, between Robert Bruce and Edward II. of England, June 24, 1314.
Scone	In Perthshire, on the Tay	2,381	Noted for its palace where the kings of Scotland used to be crowned.
Melrose	In Roxburghshire, on the Tweed	966	Noted for its magnificent abbey, founded by David I. in 1136. The ruins are the most entire and beautiful in Scotland.

12. Vegetable Productions.—Except in so far as the growth of plants is modified by climate, the vegetable productions are specifically the same as those of England; but from the higher latitude and general altitude of the land, they partake more of an alpine character. Unless in very sheltered, low, and finely exposed situations, many of the ornamental shrubs and exotic trees which adorn the lawns of English gentlemen, will not grow at all in the open air in Scotland. Even the forest trees of England are unable to withstand the severity of a Highland winter, and the native pine and birch alone arrive at maturity; but, in the Lowlands, English forest trees arrive at the usual perfection. In Scotland, however, we arrive at the limit where all timber trees cease to grow; and in almost all the islands, and many extensive tracts of the mainland, not a tree is to be seen.

From the great extent of surface occupied by sterile mountains, elevated moors, rocks, bogs, and morasses, the cultivated lands are still limited. The agricultural capabilities of the British islands were estimated as follows, by Mr. Couling, in 1827, and although the country has undergone a vast improvement since then, the table will still give a good idea of the comparative fertility of England and Scotland:—

Country.	Arable and Gardens.	Meadows, Pastures, and Marshes.	Wastes capable of improvement.	Wastes incapable of improvement.	Total.
England	10,252,800	15,379,200	3,454,000	3,256,400	32,342,400
Wales	890,570	2,226,430	530,000	1,105,000	4,752,000
Scotland	2,493,950	2,771,050	5,950,000	8,523,930	19,738,930
Adjacent Islands	109,630	274,060	166,000	569,469	1,119,159
Acres.	13,746,950	20,650,740	10,100,000	13,454,799	57,952,489

In the Lowlands of Scotland, however, agriculture is better understood than in most other countries, and the improvement in the soil, the cultivation of waste lands, and the increase in the production, which have consequently taken place during the last fifty years, are almost incredible. All the common grains are cultivated profitably and very extensively in the Lowlands; but oats, and a coarse variety of barley, are the only grain crops grown in the upper districts of the Highlands and Islands. The vegetation of Scotland, in short, wants that richness and luxuriance which form so peculiar and beautiful a feature of the fertile vales of England; but the more bracing climate of the former gives an energy and an industry to its inhabitants, which in a great measure counterbalances this deficiency in a financial point of view.

13. Animals.—The same remark applies to the animals of Scotland which was made in regard to its vegetation,—that they are specifically the same as those of England, but that, from the same causes, they present characteristic differences.

(1.) *Domesticated Quadrupeds.*—The quadrupeds are nearly the same as those in England, but smaller in size; a great number of sheep and black cattle are reared, immense numbers of which are sent to the London market, where they are much prized for the delicacy of their flesh. Scotland still retains several breeds of animals peculiar to itself, and apparently best adapted for its soil and climate—such as the Clydesdale, Galloway, and Shetland breeds of the *horse*; the Aberdeenshire, Ayr, Fife, Angus, and West Highland breeds of the *ox*; the Cheviot sheep of the south, and the black-faced hardy wether of the north. The *stag*, the *roe*, and the *wild cat*, are the only wild animals peculiar to the highland mountains.

(2.) *Birds.*—The *grouse*, *partridge*, *woodcock*, *blackcock*, *ptarmigan*, and *capercailzie*, are very abundant in some localities; the grouse, in particular, are plentiful over most of the Highlands, the shooting of which, in their season, forms one of the most interesting and fashionable sports of the day.

(3.) *Fish.*—The rivers of Scotland produce a far greater abundance of *salmon*, *trout*, *pike*, and *perch*, than those of England; consequently, the capture and exportation of salmon for the London market forms a considerable branch of commerce; but there are fewer species of fresh-water fish in Scotland than in England; many of the sea-fish, pilchard, mackerel, and white bait, are uncommon or scarcely known; while others are more plentiful than on the English coasts, as cetacea, herring, cod, and other white fish.

14. Geology of Scotland.—The high lands and other mountainous parts of the country are composed almost entirely of primary formations, granite, gneiss, trap, greenstone, and other early igneous rocks, constituting one of the best specimens of a primary country; while in the low lands of the central and southern portions of the kingdom we find the secondary formations, as old red sandstone, carboniferous limestone, and coal measures, with their associated traps and basalts.

15. Industrial Resources.—The productive industry of Scotland has increased enormously since the commencement of the present century; the value of the land during

this period has been nearly doubled. By the excellent system of letting farms under leases of nineteen years, by the application of mechanical skill to the mechanism of implements of husbandry, and by the light which chemistry has thrown on the nature of soils, and on the application of artificial manures, the science of agriculture has, in many districts of Scotland, arrived at a degree of advancement which can scarcely be met with in any quarter of the world.

Independent of the value of cattle, sheep, wool, and dairy produce, which we have not sufficient data to estimate correctly, the total annual value of the land produce, including crops, pastures, gardens, and woodland, has been calculated at upwards of £30,000,000.

The salmon fisheries at £170,000.

The herring fishery produces 660,000 barrels.

Cod and whitefish fisheries very large amount, but unknown.

Shellfish and cetacea, a considerable amount.

Cotton manufacture, valued at £5,000,000 per annum.

Paper-making is conducted on a large scale in Mid-Lothian, Fife, and Aberdeen.

Scotland has now a large trade in iron-founding; it is carried on extensively and prosperously in the counties of Lanark and Stirling; engine-building and machinery of every kind is extensively constructed; shipbuilding is carried on extensively at Aberdeen, Arbroath, Glasgow, and Dumbarton; Glasgow and other ports on the Clyde being most celebrated for steamers both of wood and iron, and Aberdeen for clipper ships. *Type-founding*, *printing*, and *publishing*, are conducted on a large scale in Edinburgh and Glasgow. *Leather*, *chemical products*, *glass-wares*, *soap*, &c., are also extensively manufactured. *Brewing* and *distilling* constitute a considerable portion of the trade of the country. *Highland whisky* and *Scottish ales* have long and deservedly enjoyed an extensive celebrity.

The chief mineral productions of the country are :—

Granite of excellent quality, wrought at Aberdeen, Peterhead, and Kirkcudbright.

Marble at Assynt; *serpentine* at Portsoy.

Slate at Ballahulise, Aberdeenshire, &c.

Limestone in almost every county.

Building stones of first-rate quality in Fife, Mid-Lothian, &c.

Coal at the extensive fields of Fife, Mid-Lothian, Linlithgow, Stirling, Lanark, and Ayr.

Ironstone in most of these coal-fields, but chiefly at Lanark.

Lead in a great measure from the Lowther hills.

Silver is extracted in small quantities from the lead.

Strontian is found in Argyleshire.

Alum is procured in large quantities from the coal-shales near Campsie and Hurlet.

Clay, for tiles and bricks, is found extensively.

Precious stones are also found, as garnet, rockcrystal, cairngorum, agate, &c.

Extensive and flourishing as the various *manufactures* have become, the commerce of Scotland has more than kept pace with them. The mercantile navy of Scotland, exclusive of passenger steamers, &c., number upwards of 3500 vessels, with a tonnage of 19,422 tons. The internal communication of the country is now greatly facilitated by railways, of which 600 miles are either made or in the course of construction; these, in addition to the numerous excellent macadamised roads which previously existed, with canals of a total length of 150 miles, will vastly contribute to the opening up of all the resources of the country.

16. Political Constitution.—The victory of Bruce over King Edward of England at Bannockburn, was the turning point which secured the independence of Scotland as a nation; the union of its crown with that of the sister country by the hereditary right of James VI., and the legislative union in 1707, have all been productive of the most important and beneficial results to Scotland. Since the latter period, the government of the country has been identical with that of England in its leading features; although in Scotland the law courts, both civil and criminal, are more simple and efficient than in England.

17. Religious and Educational Institutions.—"With respect to *religion* and *education*, the Scotch have long enjoyed a high reputation; higher, however, than is warranted by existing facts. The national religion is Calvinistic in doctrine and Presbyterian in government—a sort of ecclesiastical republic, in which all the clergy are equal in status. The church is supported by teinds and glebe lands, aided in some instances by parliamentary grants, and resolves itself into parochial charges of unequal extent and revenue;" the parishes amounting to 1023. Dissenters consist chiefly of those seceding from the kirk, whose ritual they observe; the most important secession took place in 1843, and is called the *Free Church*. The other denominations of Christians are Roman Catholics, Independents, and Episcopalians.

The chief educational establishments on a large scale are the four universities of St. Andrews, Aberdeen, Glasgow, and Edinburgh, which are open to students of all denominations. The university of St. Andrews was founded in 1411, by Henry Wardlaw, then bishop of St. Andrews; it was once a celebrated seat of learning, and is still well endowed, but its glories departed with the Scottish Reformation, when the cathedral of St. Andrews and most of the other ecclesiastical buildings were demolished, in June, 1559, by a mob, who were excited by a sermon of the celebrated John Knox. At Aberdeen there are the University and King's College in Old Aberdeen; and Marischal College in New Aberdeen. King's College was founded by Bishop Elphinstone, in 1494; Marischal College was founded by Earl Marischal, in 1593. The University of Glasgow was founded by a bull of Pope Nicholas V., granted in 1450. The University of Edinburgh was founded by James VI. of Scotland, by a charter dated 24th April, 1582.

"There are a number of minor colleges connected with the Catholic, Episcopalian, and Free Churches; a number of academies and grammar schools established in the cities and burghs; several excellent institutions endowed by private bequests; and the elementary schools in connection with the Established Church in every parish, and nearly as many connected with the Free Church." By these means the rudiments of a sound education are, perhaps, more widely disseminated in Scotland than in most other countries.

AGRICULTURE.

CHAPTER XIII.

FARM STEADINGS.

A farm steading does not necessarily include the farmer's house; the extent, accommodation, and site of which, must depend upon the taste of the farmer, or, as is usually the case, the opinion that the landlord holds with regard to what he thinks should be the taste of the farmer. The steading includes those farm buildings intended to store farm produce, prepare such for the market, afford a home to the animals that are bred, fattened, or labour a farm, and safe places for keeping the implements of culture. It also, at least in those parts of the country to whose farming practices we especially refer, includes the houses for the farm servants.

The arrangements of the steading will, of course, vary very much in different farms, according as to whether they are dairy ones, pastoral, carse, &c. The following observations are meant to apply to a farm upon which mixed husbandry is followed.

As straw is a bulky article, and one that is in daily demand, and, moreover, as it requires to be distributed daily by hand, the place where it is stored, or the straw-barn, should be the most centrically placed of any in the steading. The thrashing-machine, again, should be so situated as to replenish the straw-barn with straw with as little labour as possible. The stack-yard, with the unthrashed stacks, should be convenient to the thrashing-mill; and the houses, &c., for the animals should be placed nearest to the straw-barn, in proportion as their inmates

require a greater daily supply of straw. Thus, the young cattle require most straw of all, usually getting little else, and their court should be nighest to the barn. Fattening cattle require less, but still the next largest quantity, and therefore ought to come next; while cows and horses consume still less, and, consequently, should be in the remotest houses, byres, or stables.

The upper barn, which receives a taken down stack, and the corn barn, where the new thrashed corn is deposited as soon as it is thrashed, of course must depend for their situation upon the thrashing-mill.

Cattle courts, &c., should always be open to the south, and sheltered from the north.

These general remarks may give an outline of what we mean. We now proceed to expand upon a few particulars. We commence with the construction of—

WORK-HORSE STABLES.

Stables are seldom made wide enough, and six yards ought to be the minimum. The stalls are usually made about five feet three inches in width, but this does not allow sufficient room for grooming, or for the horse turning to scratch himself. They ought to be two yards wide. The hay or straw rack is commonly placed high up, so as to compel the horse to hold up his head, in order to apprehend his food; but of late, and we think with propriety, this has been altered, and the hay-rack has been placed low down, so as to give the horse as little trouble as possible in obtaining its contents. At the near end of the rack is placed the manger to hold the corn and the mashes. Mangers are constructed of stone or wood, but preferably of the latter. The traverses are made of wood, and the hind parts of them of either wood or iron.

The floor of the stable requires to be made hard, so as not to be destroyed by the horse's feet. Usually it is formed of boulders imbedded in sand, and sometimes now large flags are employed for the purpose. When these latter are used, small grooves should be made across them with a chisel, so as to make them not liable to slip the horse. Behind the stall there is a gutter, to carry away the urine, &c. There is an idea that the floor of stalls should slant upwards a good deal, which is probably an erroneous one.

Far too little pains used to be bestowed upon ventilation of stables, and although there is a visible improvement in this respect, even yet the necessity of a due supply of fresh air is not sufficiently appreciated. In order to let the impure air out, any of the ventilators in common use may be employed, and a number of openings, covered with perforated pieces of metal, should be provided, to let the fresh air in.

BYRES.

Byres are the parts of the steading in which milch cows are kept, and also, upon some farms, fattening cattle. In them the animals stand in stalls. These stalls, when intended for single animals, are usually made about four feet only in width, which is too small. If a byre is intended to receive only one row of animals, the proper width of it is about eighteen feet. This gives two feet for the manger, eight for the cow to stand or lie upon, a foot of gutter behind the beast, and seven feet for a passage for the attendants. Every second single stall, or every double one, if double stalls are preferred, should have a ventilator. In all modern-built byres there is no room above, they being one-storied erections. The door is almost uniformly divided into an upper and a lower half, each opening separately.

The stall travises are sometimes made of wood, sometimes of iron, and are generally about a yard in height. In length they do not reach to within from one to two feet of the end of the cow. Very often, indeed, but improperly, these travises are altogether omitted. We just mentioned that the racks of horses were placed very high up. Those of cows are almost uniformly situated upon the ground. But a little elevation renders them far more convenient to the animal. It is also of importance to take care that the mangers of horned cattle are not placed too near the wall, in which case their horns prevent them from having ready access to them.

The floor of byres is best paved, in the gutter, by flags, and, where the animal's hind legs are, boulders, or small stones. The space over which the forepart of the cow or ox is to be, had better be composed of beaten earth. The reason of this is that cattle, in lying down and in getting up, first kneel upon their fore knees, and their heavy weight is apt, if they do so upon very hard surfaces, to produce sores.

Cattle in stalls are bound to a stake by a chain that goes round their necks. It effectually prevents them from turning to lick themselves, and is objectionable.

HAMMELS.

" Hammels," says Stephens, who is one of the most earnest advocates of these plans of shelter for fattening cattle—" hammels consist of a shed and of an open court, communicating by a large opening. The shed part need not be so wide as the rest of the apartments in the farm-stead, in so far as the comfort of the animal is concerned; and in making it narrower, considerable saving is effected in the cost of the roofing.

" There is no definite rule for the size of hammels, but as their advantage consists in assorting the cattle according to their age, temper, size, and condition, and in giving them liberty in the fresh air, they should not only be much smaller than courts, but only contain two large oxen, or three small ones. Hammels, however, are often made much larger than this. When the dung is proposed to be taken away by horses and carts from the courts, these should not be less than thirty feet in length, by eighteen feet in breadth, and the entrance gate nine feet in width; and this size will easily accommodate four oxen, which will each attain the dead weight of seventy imperial stones. But the dung may be taken out with barrows, and a court fifteen feet in length, by twelve feet in width, free of the turnip trough, will accommodate two such oxen as these.

" The sheds to both these sizes of courts need not exceed fourteen feet in width, and their length is equal to the width of the courts.

" To give permanency to hammels, the sheds should be roofed, like the other buildings; though, to save expense, many farmers roof them with small trees, placed close together upon the walls of the sheds, and build thereon straw, corn, or beans. This is an excellent plan for a stack of beans or peas, but the finished building is best adapted for its own purpose. Temporary erections are constantly requiring repairs, and in the end cost as much as substantial work."

It is an important question whether, upon the whole, beasts do better in hammels or in byres. Upon the whole, the evidence is in favour of the former. It requires not only a good deal of labour on the part of the servants, but also constant superintendence on the part of the master, to keep cattle clean in byres; while in properly constructed hammels they keep themselves clean well enough. In like manner, the hair of hammel-inhabiting cattle is kept in a healthier state than that of those living in byres. Then hammel-fed beasts travel better. But what is of more importance than anything else, hammel-fed beasts are more profitable, and hammels cost much less than byres.

BOXES.

We merely mention these to state, that the new-fashioned box for fattening cattle is an ill-constructed and small hammel, and in every respect inferior to its original.

PIGGERIES.

The brood-sows, the boar, and the weaned pigs, not yet put up to fatten, do best of all in a large hammel. Separate buildings, however, require to be erected for the sows to farrow in, and for the fattening pigs.

The sty for a breeding sow should have two divisions, one about six feet square, covered by a roof, for the sow to litter in and to nurse in, and the other an open court for her to receive her food in.

Sties for fattening pigs should also consist of two apartments, one covered in, about four feet square, to hold two animals, and the other a feeding-court.

In both cases, the inner apartment should have a wooden floor, with a slant in one direction.

LIQUID MANURE TANKS.

The liquid from stables, byres, hammels, and piggeries, (and courts, whether for young stock—a consideration of which we here omit, as they are rapidly and deservedly going out of use—or for manure heaps,) should be conveyed by properly constructed drains to a receptacle, or liquid manure tank.

The drains leading to the liquid manure tank require to have a considerable declivity. The tank itself ought to be built of stone or lime, and there should be a pump communicating with it.

All the buildings in the steading should be effectually provided with spouts, so as not to run the chance of having any of the manure, or the soluble parts of it, washed away.

THE STACKYARD.

The stackyard should always be enclosed, and, which is very rarely done, provided with as many stalkets as it is supposed there will be stacks. These stalkets are sometimes made of iron, but more usually of stone supports, surmounted by a wooden frame. The damage inflicted by rats and mice to stacks placed upon the ground is probably very great. When, however, the number of these stalkets is limited, the grain that will be latest in being thrashed, that is to say, wheat and oats, should be placed upon them.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING: THE CALOTYPE, DAGUERREOTYPE, &c.

CHAPTER VII.

PROCESS ON GLASS WITH COLLODION.

Mr. Thornthwaite justly remarks, that "for obtaining views and representations of fixed objects, where time is not of so great importance, and it is absolutely necessary to employ a dry plate, the employment of albuminized glass plates will be found preferable to those prepared with collodion." With albumen, however, it is difficult to obtain an even coating; it requires careful drying, and is so extremely delicate when damp that it will not bear the slightest handling. The time required in the process, is also an objection to its use in taking portraits. For this purpose, the new process with collodion, which promises to be as useful as it is simple and beautiful, presents decided advantages. "The practice of taking pictures in the camera by means of the solution of collodion on glass," says an anonymous writer, "is so simple, so easy in execution, and so rapid in its results, that there is little doubt, not only that the use of paper will be abandoned, but that daguerreotypes will give place to positives taken by this means, which are less expensive, more correct (as by viewing the picture *through* the glass the proper position of objects is got), and *at least* as sensitive." We have seen, on the other hand, that M. Le Gray is of opinion, "the future of photography is altogether in paper;" but this must depend on the improvements that are made in the use of that material; and without hazarding conjectures as to what *may* be, no doubt can exist that the glass process with collodion is not only simple in its use, but exceedingly beautiful in its results. "This process," says the translator of Gustave Le Gray's treatise, recently published by the Messrs. Willatts—"this process, as practised by M. Le Gray, M. Martens, and other French and English amateurs, gives pictures as fine and distinct as those of the daguerreotype, with less hardness, and with the inestimable advantages of having no metallic reflection, and being capable of reproduction to an almost unlimited extent."

To Le Gray has been assigned the merit of first proposing the use of collodion in photography; but it is remarkable that this point, although it refers to the most recent important discovery, and to one which promises quite a revolution in the art, does not appear to be satisfactorily settled. It is admitted, however, that to Mr. Frederick Scott Archer is due the merit of having first described the method of applying collodion, in a communication to the "Chemist," dated 18th February, 1851.

Collodion is a preparation formed by dissolving gun-cotton in ether. It is a very mucilaginous solution, and the ether evaporating leaves behind a film of the utmost transparency. "It presents," says Mr. Archer, "a perfectly transparent and even surface when poured on glass, and being in some measure tough and elastic, will, when damp, bear handling in several stages of the process." The film, indeed, may be separated from the glass plate after the picture is finished; and though this is not generally done, it obviates the absolute necessity of having a large stock of glass when a number of pictures are to be taken.

It is not all kinds of gun-cotton which dissolve equally well in ether. That prepared by the process of M. O. Livinius is the best. For this purpose, half an ounce of dried nitrate of potassa, in fine powder, is to be mixed with three-fourths of an ounce of ordinary strong sulphuric acid in a porcelain or glass cup, with a glass rod, and half a drachm of clean dry cotton is then quickly added, and stirred about in the mixture for about five minutes. When removed, the cotton should be carefully washed with water, and dried in a warm atmosphere.

To prepare the collodion, ten grains of the gun-cotton thus obtained are dissolved in half an ounce of sulphuric ether, to which is added one drachm of alcohol. This gives a complete and transparent solution, of the consistence of a thick mucilage of gum; and this substance is now to be treated in much the same manner as the albumen in the preceding processes.

In the first place, to iodize it, five grains of iodide of potassium is dissolved in the smallest quantity of water; this is saturated with iodide of silver, and added to the collodion, together with about three ounces of sulphuric ether, so as to enable it to flow freely over a glass plate. It has also been recommended to add one grain per ounce of arsenious acid, and a very little binoxide of potassium; but these are not essential, although they may possibly exercise a beneficial effect.

The method recommended by Mr. Archer is as follows:—"To a solution of iodide of potassium in spirits of wine, add a small quantity of iodide of silver, sufficient to saturate the iodide of potassium; let, however, the latter salt be in excess. Add a small quantity of this solution to the collodion, between five and ten grains by measure to one ounce of collodion will be sufficient, and if any of the iodide of silver should precipitate, a small quantity of iodide of potassium must be added to dissolve it."

The next step is to spread the solution evenly on a plate of glass, which should be of thin plate glass, cut to the size of the camera frame, and slightly ground on its edges; and care should be taken to have it properly cleaned before use. Mr. F. Horne, in a communication to Mr. R. Hunt, published in the "Art Journal" of July, 1851, gives very minute and able directions for the process, which we shall present to the reader in his own words:—

"Collodion, as most people are aware, is a solution of gun-cotton in ether, and, for the purpose now under consideration, should contain a small quantity of iodide of silver dissolved in iodide of potassium. It should be sufficiently limpid to run freely over a plate when poured on, or ether must be added until this result is obtained. If the collodion be too thick, great difficulty will be experienced in obtaining an even coating; but when of a proper consistency, plates of any size may be coated. The plan which I have adopted, and with great success, is as follows:—Take a piece of flat glass cut to the size of frames, and having washed it with water, and wiped the same quite dry, then, while holding it at one corner, or, if large, placing it on a levelling stand, pour on the centre of the plate a good body of the prepared collodion, which will readily diffuse itself equally over the surface. Immediately pour the liquid off again into the bottle from one corner, and bringing the hand holding the plate down a little, that the liquid may run to the lower edge, and drawing the mouth of the bottle along, those lines first formed will run one into the other, and give a flat even surface. Very little practice will soon enable any operator to obtain this result. The plate is now immediately, and before the whole of the ether has had time to evaporate, to be immersed in a bath of nitrate of silver (thirty grains to the ounce of distilled water), until the greasy appearance which it first presents on immersion is entirely gone, and the silver

solution flows freely over the surface. It should then, in its moist state, be placed in the camera and the picture taken, the time of exposure varying of course with the light; but for a portrait, and with a moderately quick lens, from three to thirty seconds will be sufficient. Mr. Fry, with the collodion, has obtained beautiful portraits by placing the sitter in the open air, and simply removing the cap from the lens, and closing it again as soon as possible. The agent for developing these pictures is the pyro-gallic acid, as recommended by Mr. Archer; and I am told the proto-nitrate of iron also answers equally well. The solution of pyro-gallic acid should be made as follows:—

Pyro-gallic acid, ...3 grains.
Glacial acetic acid, ...1 drachm.
Distilled water,..1 ounce.

The plate, after being exposed in the camera, is to be placed, face upwards, upon a levelling stand, and a sufficient quantity of the above solution should be poured equally and quickly over the surface, and the picture allowed to develop, occasionally moving the plate to prevent any deposit from settling at one spot. A few drops of a solution of nitrate of silver—five grains to the ounce—may also, in dull weather, be added to the pyro-gallic with advantage, just before pouring it over the plate; but in very bright weather, the picture will develop sufficiently quick with the pyro-gallic acid solution alone. The development may be readily judged of, by holding a piece of white paper occasionally under the plate, and as soon as sufficient intensity has been obtained, the solution must be poured off, and the plate washed by a gentle stream of water. After this, the surface should be covered with a saturated solution of hyposulphite of soda, which will almost immediately remove the undecomposed iodide and fix the picture, and another stream of water must then again be poured over to free the plate from hyposulphite, and the picture is finished.

"In this state the pictures are more or less negative by transmitted light, and, if not too much brought out, positive by reflected light. But I have found the most beautiful and decided positives may be obtained, by the simple addition to the pyro-gallic solution of a minute quantity of nitric acid, care being taken not to add too much. I have also obtained purple and green pictures; the former by adding acetate of lead, and the latter with acetate of lime and ordinary gallic acid.

"The pictures thus obtained may be treated as negative pictures, and printed from by any of the methods employed to obtain positive pictures from paper negatives."

We may add, that when the picture has been finished and fixed, it may be protected from injury, and greatly improved in effect, by pouring over its surface some mastic varnish, diluted with camphine, and coating the other side with black japan varnish.

"If thought more convenient," says Mr. Archer, "and in fact this mode is the best when pyro-gallic acid is used, the film of collodion, after being exposed to light and the image developed, can be removed from the glass plate (leaving the fixing and final washing to be done at leisure), by rolling it up on a glass rod, thus:—Take a sheet of ordinary white wrapping or thick blotting paper (if glazed it will be better), about the same breadth, and about one-third longer than the drawing to be removed; soak it in water, and place it with the glazed side in contact with the surface of collodion. Turn the end of the collodion picture over the edge of the paper lying upon it; then place the glass rod just within the edge, and commence rolling it upon the rod. With a little dexterity this can be accomplished without injuring the drawing. The cylinder thus formed is easily removed from the glass rod, and can be preserved for any length of time in this state by being kept damp and away from the light, to be finally fixed at some more convenient time. Thus, one plate of glass will be sufficient to make any number of drawings upon, the above operation being repeated for each picture. The plate of glass should be rather larger than the drawings intended to be made upon it, to allow for rough edges, &c. The back of the glass may be ground to get the focus upon, and one side should be formed into a kind of handle to prevent the hand of the operator being near the solution when the glass is in use."

To contain the bath of nitrate of silver, a flat dish may be formed either of glass, porcelain, or gutta percha, and care must be taken to keep the solution perfectly free from dust. With this precaution, it will serve for a great number of pictures, and will only require to be renewed, should it, by accident, get the smallest quantity of hyposulphite of soda in it, or else fail to produce an even film of iodide when the plate is immersed.

Nothing can exceed the extreme sensibility of plates prepared with collodion, when the process has been properly managed. "By this method," says a gentleman who has been very successful in his preparations, "pictures of moving objects can be got—vessels sailing, the waves of the sea, and men and animals walking. In bright sunshine, and with the solution of nitrate of silver, and the developing solution warmed to 90° or 100°, it is impossible to open and shut the camera sufficiently quickly, and some other method must be adopted than the usual slide, which is quite unfit. Portraits are readily taken in four or five seconds without sun, and in rooms in about thirty seconds."

INORGANIC CHEMISTRY.

CHAPTER IV.

BEHAVIOUR OF ACIDS.

The non-metallic acids, whether organic or inorganic, may, for analytical purposes, be divided into two groups, accordingly as they form a precipitate with chloride of barium or not. The former class we will briefly consider in detail.

1. Boracic acid gives, with *chloride of barium*, a white precipitate, soluble in acids, sal-ammoniac, and excess of water; with *nitrate of lime*, a white precipitate, soluble in sal-ammoniac, and excess of water; with *sugar of lead*, a white precipitate, soluble in acids; and with *nitrate of silver*, a white precipitate, soluble in acetic acid. If a pulverized borate is moistened with a few drops of strong sulphuric acid in a small porcelain dish, alcohol, poured upon the mass and ignited, burns with a green flame. On stirring, or extinguishing and rekindling the flame, this colour is more distinct.

2. Bromic acid gives, with *chloride of barium*, a white precipitate, soluble in water; with *acetate of lead*, a white precipitate, soluble in excess of water; and with *nitrate of silver*, a white precipitate, soluble in nitric acid. Bromates explode if heated along with charcoal; and if treated with cold sulphuric acid in a test-tube, they evolve deep-red vapours of bromine.

3. Carbonic acid yields, with *chloride of barium* and *nitrate of lime*, white precipitates, both soluble in muriatic acid; with *acetate of lead*, a white precipitate, soluble in nitric acid; and with *nitrate of silver*, a white precipitate, soluble in ammonia.

4. Citric acid gives, with strong solutions of *chloride of barium*, a white precipitate; with *nitrate of lime*, a white precipitate, soluble in sal-ammoniac; with *sugar of lead*, a white precipitate, soluble in excess of ammonia; with *nitrate of silver*, a white precipitate; with *subnitrate of mercury*, a precipitate.

5. Hydrofluoric acid and soluble fluorides give, with *chloride of barium*, a white precipitate, soluble in hydrochloric acid; with *nitrate of lime*, a voluminous white precipitate, sparingly soluble in hydrochloric acid; with *acetate of lead*, a white precipitate, soluble in hydrochloric acid.

6. Iodic acid gives, with *chloride of calcium*, *nitrate of lime*, *acetate of lead*, and *nitrate of silver*, white precipitates, all soluble in nitric acid; the last-mentioned also in ammonia. If iodates are heated in a test-tube, oxyen gas is liberated, and may be detected by its causing a glowing match to burst into flame. An iodide remains behind.

7. Oxalic acid forms, with *chloride of barium*, a white precipitate, soluble in acids, but nearly insoluble in water; with *nitrate of lime*, a white precipitate, insoluble in water, salts of ammonia, excess of oxalic and acetic acids; with *acetate of lead*, a white precipitate; with *nitrate of silver*, a white precipitate, soluble in nitric acid and ammonia. Oxalic acid and solutions of oxalates, along with hydrochloric acid, reduce perchloride of gold on boiling, more readily than the organic acids.

If solutions of acid oxalates are poured upon peroxide of manganese, carbonic acid gas is disengaged with effervescence.

8. Phosphoric acid, in combination, forms precipitates with solutions of the *chlorides of barium* and *calcium*, with *lime* and *baryta water*. These precipitates dissolve in nitric and hydrochloric acids, and in ammoniacal salts. With *sulphate of magnesia*, phosphoric acid produces a precipitate on the addition of ammonia; with *nitrate of silver*, a yellow precipitate, soluble in nitric acid, ammonia, and nitrate of ammonia. If *molybdate of ammonia* be added to the solution of a phosphate, heated, and then an excess of nitric acid added, a very bright yellow precipitate is formed.

9. Phosphorous acid gives, with *chloride of barium*, a white precipitate, soluble in muriatic acid and sal-ammoniac; with *nitrate of lime*, a white precipitate, soluble in nitric acid; with *acetate of lead*, do; with *nitrate of silver*, a brown precipitate. The phosphites are converted into phosphates at a red heat, hydrogen gas being given off.

10. Selenic acid gives, with *chloride of barium*, a white precipitate, insoluble in nitric, but soluble in boiling hydrochloric acid; with *nitrate of lime* and *nitrate of silver*, white precipitates, soluble in nitric acid; with *acetate of lead*, a white precipitate, insoluble in nitric acid. If the seleniates are boiled with hydrochloric acid, it is decomposed, and chlorine evolved. (See also Blowpipe.)

11. Silicic acid forms, with *chloride of barium*, a white precipitate, soluble in dilute hydrochloric acid; with *nitrate of lime*, a white precipitate, soluble in dilute nitric acid; with *acetate of lead*, a white precipitate, soluble in nitric acid and in potash; and with *nitrate of silver*, a yellow precipitate, soluble in dilute nitric acid. After ignition, silicic acid is insoluble in every liquid except hydrofluoric acid. (See Blowpipe.)

12. Sulphuric acid gives, with *chloride of barium*, a white precipitate, insoluble in acids; with *acetate of lead*, a white precipitate, very soluble in tartrate of ammonia; with *nitrate of lime*, a white precipitate, soluble in an excess of water.

13. Sulphurous acid forms, with *chloride of barium*, a white precipitate, soluble in hydrochloric acid; with *nitrate of lime*, a white precipitate, soluble in excess of water; with *acetate of lead*, a white precipitate, soluble in dilute nitric acid; with *nitrate of silver*, a white precipitate, soluble in nitric acid and ammonia. If a solution of green manganate of potash has been reddened by the addition of an acid, the red colour is again removed on adding a soluble sulphite. If a solution of protochloride of tin in muriatic acid be added to the solution of a sulphite, the liquid, after some time, turns brown.

14. Tartaric acid gives, with *chloride of barium*, a white precipitate, soluble in excess, and in dilute acids; with *nitrate of lime*, a white precipitate, soluble in ammoniacal salts; with *acetate of lead*, a white precipitate, soluble in ammonia; with *nitrate of silver*, a white precipitate, soluble in ammonia, and reduced by boiling; with *sulphate of potash*, a white crystalline precipitate.

II. NON-METALLIC ACIDS NOT PRECIPITATED BY CHLORIDE OF BARIUM.

1. Acetic acid. If its salts are mixed with equal weights of alcohol and sulphuric acid, the odour of acetic ether is perceptible on the application of heat. Solutions of neutral acetates give an intense blood-red tinge, if added to a neutral *persalt of iron*. All free acids except the acetic destroy this colour. The acetates give a crystalline precipitate with *subnitrate of mercury*.

2. Benzoic acid is precipitated from its soluble salts by stronger acids in the form of a white powder; with a neutral persalt of iron, it gives a bulky yellowish-brown precipitate.

3. Chloric acid is not precipitated by bases or salts. Chlorates explode if heated along with organic matter; with sulphuric acid they evolve greenish-yellow vapours of peculiar odour. Caution!

4. Formic acid gives, with *nitrate of silver*, a black precipitate of metallic silver. It agrees with acetic acid in its behaviour with persalts of iron. With concentrated sulphuric acid, the formiates, on being heated, evolve carbonic oxide gas. They reduce salts of mercury and silver more rapidly than the acetates.

5. Hydrochloric acid and chlorides give, with *sugar of lead*, a sparingly soluble white precipitate; with *nitrate of silver*, a white precipitate, soluble in ammonia and blackened by sunlight. Insoluble chlorides may be mixed with carbonate of soda, and ignited in a porcelain crucible. Chloride of sodium is formed, which may then be tested in the ordinary manner. To detect chlorides in presence of bromides, the substance is pounded along with chromate of potash, placed in a retort, drenched with fuming sulphuric acid, and heated. A blood-red liquid distils over, which, if chlorine is present, forms a *yellow* solution with excess of ammonia.

6. Hydrocyanic acid and cyanides form a white precipitate with *acetate of lead*; with *nitrate of silver*, a white precipitate, insoluble in dilute nitric acid, but soluble in ammonia and cyanide of potassium. With a solution of *green vitriol*, which has been for some time exposed to the air, alkaline cyanides give a blue precipitate. For free hydrocyanic acid, it is necessary to add first a little caustic potash, then the green vitriol, and lastly an excess of hydrochloric acid. With a drop of *persulphuret of ammonium*, a few drops of any liquid containing hydrocyanic acid, form, on heating, a colourless solution, in which persalts of iron strike a deep blood-red.

7. Hydrobromic acid and bromides give, with *acetate of lead*, a white precipitate, soluble in nitric acid; with *nitrate of silver*, a yellow precipitate, insoluble in dilute nitric acid, and soluble in excess of ammonia; with *chloride of gold*, solutions of bromides produce a red tinge. A more delicate test is the following:—A little peroxide of barium is put into a test-tube with distilled water and pure hydrochloric acid; then, as soon as bubbles appear on the surface, ether, and the substance suspected. The liquid is shaken, and the bromine, if present, dissolves in the ether with a yellowish colour.

8. Hydriodic acid and iodides give, with *acetate of lead*, a yellow precipitate, soluble in nitric acid and boiling water; with *nitrate of silver*, a yellow precipitate, insoluble in nitric acid, and very sparingly soluble in ammonia. The same process may be followed which has just been laid down for bromides, employing, however, instead of ether, starch, with which iodine gives a deep blue colour.

9. Hydroselenic acid forms, with *acetate of lead* and *nitrate of silver*, black precipitates. (See Blowpipe.)

10. Hydrosulphocyanic acid gives with *persalts of iron* a blood-red tinge, which may be distinguished by the addition of corrosive sublimate from the similar colour produced by meconic and acetic acids. The redness resulting from the two latter acids is not affected by this addition, whilst that from the former is destroyed.

11. Hydrosulphuric acid gives a black precipitate with salts of lead and silver. It is also recognized by its colour. Soluble sulphurets strike a beautiful purple with the *nitro-prussiate of potassium*.

12. Hyposulphuric acid. Dry salts of this acid, if heated, evolve sulphurous acid, whilst a sulphate remains behind.

13. Hyposulphurous acid gives, with *acetate of lead*, a white precipitate, slightly soluble in nitric acid; with *nitrate of silver*, a white precipitate which afterwards turns black. With *muriatic acid* the solution becomes milky, whilst sulphurous acid is evolved.

14. Nitric acid. About half a drachm of pure strong sulphuric acid is put in a test-glass, along with a few drops of the liquid in question. A particle of *brucia* is then added, and the whole stirred. If nitric acid be present, the liquid becomes first red, and then yellow. Or a dry fragment of the supposed nitrate is placed in a test-tube, and covered with strong sulphuric acid. Solution of green vitriol is then poured carefully in upon the sulphuric acid, so as not to mix. If nitric acid be present, a deep brown ring will appear where the two liquids meet. All shaking must be avoided. If chlorates are supposed to be mixed with nitrates, the absence of chlorides must first be ascertained by the usual tests, and the whole then heated to redness. Chlorates, if present, are thus converted into chlorides.

15. Nitrous acid. To a solution, supposed to contain a nitrite, are added one or two drops of solution of ferrocyanide of potassium. A few drops of acetic acid are then added, when, if nitrites are present, the liquid assumes a rich yellow tint. Or, a few drops of a dilute solution of iodide of potassium (free from

iodate) are mixed with a little starch paste, and then dilute hydrochloric acid (sp. gr. 1·006) added. The liquid suspected to contain a nitrite, if alkaline, must be acidulated with hydrochloric acid, and then added to the test-mixture. If much nitrite is present, a dark blue colour is immediately formed. If the quantity be small, the liquid first assumes a pale fawn colour, and changes then ultimately to plum, violet, and finally dark-blue.

15. Perchloric acid. Perchlorates behave like chlorates, except that they are not acted upon in the cold by sulphuric and muriatic acids.

16. Succinic acid gives, with *acetate of lead*, a precipitate; with *subnitrate of mercury*, a white precipitate; with neutral *persalts of iron*, after standing, a bulky cinnamon-coloured precipitate. Succinic acid does not reduce salts of gold even with the aid of heat.

III. METALLIC ACIDS PRECIPITATED BY HYDROSULPHATE OF AMMONIA FROM AN ACID SOLUTION.

1. Chromic acid gives, with *nitrate of silver*, a brick-red precipitate, soluble in nitric acid and in ammonia; with *chloride of barium*, a canary-yellow precipitate, soluble in nitric acid. If heated with hydrochloric acid and alcohol, chromic acid and the chromates rapidly turn green.

2. Permanganic acid gives, with *nitrate of silver*, a brownish-yellow precipitate, soluble in excess of water: with *nitrate of lime*, no action; with *hydrosulphate of ammonia*, a flesh-coloured precipitate.

3. Manganic acid gives, with *nitrate of silver*, a black precipitate; with *nitrate of lime*, a black precipitate; with *hydrosulphate of ammonia*, a flesh-coloured precipitate.

IV. METALLIC ACIDS PRECIPITATED BY SULPHURETTED HYDROGEN.

1. Antimonic acid gives white precipitates with *chloride of barium*, *nitrate of lime*, and *nitrate of silver*; with *sulphuretted hydrogen*, an orange precipitate, soluble in alkalies, insoluble in cold hydrochloric acid.

2. Antimonious acid gives, with *chloride of barium* and *nitrate of lime*, a white precipitate, soluble in excess of water; with *nitrate of silver*, a white precipitate; with *sulphuretted hydrogen*, it behaves like the preceding. To distinguish it from the above, the salt in question is decomposed by muriatic acid, or by nitric acid in the cold. The residual acid is then dried, and ignited in a small retort, in order to ascertain whether it gives off oxygen gas. If that is the case, the salt is an antimoniate.

3. Arsenic acid (neutralized) gives, with *nitrate of silver*, a chocolate-red precipitate, soluble in nitric acid and ammonia; with *chloride of barium*, a white precipitate, soluble in acids and in sal-ammoniac; with *nitrate of lime*, a white precipitate, soluble in boiling water, muriatic acid, and sal-ammoniac; with *sulphuretted hydrogen*, a yellow precipitate, soluble in alkalies and alkaline sulphurets. (See also Blowpipe and Toxicology.)

4. Arsenious acid. Arsenites give, with *nitrate of silver*, a yellow precipitate, soluble in dilute nitric acid and in ammonia; with *sulphate of copper*, a pale yellowish-green precipitate, soluble in excess of ammonia and potash. Both these precipitates may also be produced by free arsenious acid, if a little ammonia is added. Arsenites form, with *sulphuretted hydrogen*, a yellow precipitate of a deeper colour than that formed by the arseniates. To distinguish between these two, they should, as soon as formed, be dissolved in an excess of ammonia. Nitrate of silver is then added, the sulphuret of silver precipitated is filtered off, and the clear liquid carefully neutralized with nitric acid. If a *red* precipitate is produced, it shows that the original salt was an arseniate; if a yellow, an arsenite. Insoluble arsenites are first dissolved in hydrochloric acid, and tested with sulphuretted hydrogen. If, however, the base is also one affected by S.H., the acid solution is saturated with ammonia; hydrosulphate of ammonia is then added in excess, so that the sulphuret of arsenic is redissolved, whilst the base remains insoluble. After filtering, dilute hydrochloric acid is added, which precipitates the arsenic as yellow sulphuret. (For the method of detecting arsenious acid when mixed with organic bodies, see Blowpipe and Toxicology.)

5. Molybdic acid gives, with *chloride of barium*, *nitrate of silver*, and *nitrate of lime*, white precipitates, soluble in water and nitric acid; the second dissolves also in ammonia, and the third in muriatic acid. With a concentrated solution, *hydrochloric acid* gives a white precipitate, soluble in excess of water; with H.S. and *hydrosulphate of ammonia*, molybdic acid forms a brown precipitate, soluble in alkaline sulphurets; with *persalts of iron*, a yellow precipitate; with *ferrocyanide of potassium* (in acid solutions), a brown-red precipitate. If an alkaline molybdate is mixed with an excess of muriatic acid, and a rod of zinc immersed in a portion of the liquid, a dark blackish-brown precipitate of protoxide of molybdenum is deposited. If this is then mixed with the other portion of the liquid and boiled. a blue colour appears.

6. Osmic acid forms brown precipitates with *nitrates of lime* and *silver*, and with *chloride of barium*; by *hydrochloric acid* it is liberated, and may be recognized by its odour.

7. Selenious acid gives, with *nitrates of lime* and *silver*, white precipitates, soluble in nitric acid; with *chloride of barium*, a white precipitate, soluble in muriatic acid; with S.H. and *hydrosulphate of ammonia*, a yellow precipitate, soluble in hydrosulphate of ammonia; with aqueous solution of *sulphurous acid*, selenious acid forms a red flaky precipitate, which, after long boiling, condenses and becomes black. If the liquor contains much nitric acid, muriatic acid must be previously added, boiling the whole, and then pouring in the sulphurous acid until precipitation takes place.

8. Tungstic acid forms white precipitates with *chloride of barium*, *nitrate of lime*, *nitrate of silver*, and *hydrochloric acid*; with *hydrosulphate of ammonia*, a brown precipitate, in solutions acidulated with hydrochloric acid. A zinc rod produces a fine blue colour in acidulated solutions of alkaline tungstates.

9. Vanadic acid forms, with *chloride of barium*, a voluminous orange-yellow precipitate, soluble in a large excess of water; with *nitrate of silver*, a voluminous yellow precipitate, soluble in nitric acid and ammonia. On exposure to the air it turns paler. With *hydrosulphate of ammonia*, the liquid turns brown, and on the addition of muriatic acid, a brown precipitate appears. Acid solutions of vanadic acid form, with ferrocyanide of potassium, a green flocculated precipitate.

BOTANY.

CHAPTER VIII.

Having adverted to the common relations of the parts, we will now speak of them separately; and, first, of the *Calyx*, or outer cup of the flower. Its leaves, called calycine leaves, when treated as individuals, take the name of *sepals;* and sometimes, according to the language in which they are written, *foliola* (*folium*, leaf), and *phylla* (φύλλον, leaf). They consist of cellular tissue, with vascular dispersions of veins and ribs, enclosing spiral vessels and woody tubes, surrounded by an epidermis, containing stomata, and on the outer surface exhibiting hairs. The ramifications of the calyx are similar to those of the common leaf, being parallel in Endogens, and reticulated in Exogens. When hairs are developed, they are called *papas*, which may be either simple, called *pilose*, as in Sweet scabious; or feathery, called *plumose*, as in that Teazel wort, known as Pterocephalus palæstinus. In Valerian worts, the hairs are rolled inwards, so as to uncoil like a spring in discharge of the fruit.

The common colour of the calyx is green, as in Asparagus; but it sometimes partakes of the gorgeous tints of the corolla, as in Fuschia and Pomegranate. In Calophyllum, belonging to the Guttifers or Gamboge family, after undergoing an enlargement the colour of the calyx changes to a fine pink. When green is present, the sepals are characterized as *foliaceous* or *herbaceous;* if a different colour prevails, they are *petaloid.*

Among the modifications which the sepals undergo, we may mention, that in the Rose, Pæony, &c., they are converted into ordinary leaves. In Mallows, the whorl of the calyx is doubled, called *caliculate*, the *epicalyx*, or outer whorl, being a sort of bractlet. In Umbelliferous plants, as hemlock, and in

Acanthads, the calyx is reduced to a marginal projection. In the Rush tribe, it becomes dry and scaly; and in Thistle, Dandelion, Artichoke, and other Composites, hairy. In all these states, it is subservient to the protection or diffusion of the seed. *Calyptra*, Plate VII., fig. 8, is equivalent to the calyx of the Mosses; and *Valva*, Plate VII., fig. 9, to that of the Fungi.

In respect of form, the calyx is sometimes *entire* (Greater stitchwort), marginally *hooked* (Rumex uncatus), and ranges from an ellipse to the oblong figure. When arched inwardly, it is *connivent;* when erect or diverging outwards, *patulous.* In Aconite, the sepals are *galeate*, or helmet-shaped; in the Violet, its segments are prolonged downwards; and when one sepal (Delphinium) or more (Indian cress) become enlarged, the calyx is *calcarate* (*calcar*, a spur).

As to arrangement, the sepals stand often separate, as in Buttercup and Wallflower, when the calyx is termed *polysepalous*, or *polyphyllous* (πολὺς, many); and the number of sepals is indicated by a Greek prefix, as *pentesepalous*, or *pentephyllous*, in a calyx of five parts, and so on; but occasionally they are, more or less, joined together, as in Harebell and Gentian worts, when they take the name of *gamosepalous*, or *gamophyllous* (γαμος, union). The junction is complete in some of the Rueworts, called Correas. When the adhesion is unequal or irregular, a *labiate*, or two-lipped calyx, is formed; and if arched, the upper lip is *ringent* (*ringo*, to grin). The divisions occasioned by these means, at the apex of the sepals, are projected, in different species, in the form of teeth, fissures, or partitions, and serve to mark their number. The lower part of the sepals, when united, constitute the *tube* of the calyx; the upper free portion of the same is the *limb.*

The calyx is said to be *caducous*, if it drops off before expansion of the flower, as in Poppy. When its fall is contemporaneous with the corolla, it is *deciduous*, as in Ranunculus; but if disarticulated at the base or middle, the lid or funnel-like form left to it, as in Encalyptus, causes it to be called *operculate* (*operculum*, a lid), or *calyptrate* (καλύπτρα, covering). The absence of an articulation determines it to be *persistent.* In this case, though no amalgamation with the fruit organ may take place, the calyx either increases after flowering—hence called *accrescent* (*accresco*, to increase), as in Common Winter-cherry—or, in some instances, it becomes *inflated* or *vesicular*, as in Strawberry trefoil; or, in other species, it continues attached in a withered state, thence called *marcescent* (*marcesco*, to decay).

Secondly, the *Corolla* now remains for consideration. This organ is sometimes altogether absent, as in the Willow; and in many of the Endogens, the blossom is more generally referable to the calyx. In some Endogens, and in the greater number of Exogenous plants, it makes its appearance as an inner envelope, next to the calyx. The leaves of the corolla are each named a *petal* (πέταλον, leaf); and though sometimes giving rise to leaf-buds from their axil, and at other times transformed into leaves, like the calyx, they really differ from both sepals and leaves. Their fabric exhibits a cellular tissue, less numerous in layers of cells than leaves, traversed by spiral vessels and transparent tubes. In some instances, the epidermis is so fine as almost to elude recognition; in other instances, it may be detached with the cuticle, displaying highly ornamental forms. The texture of the petals, indeed, varies; for in Stapelia they are fleshy; in Xylopia, or Bitterwood, coriaceous; and in Heaths, hard. On their outer surface, stomata are sometimes apparent; and though generally smooth on the surface, hairs are occasionally, but sparingly distributed.

The colouring of flowers conspicuously resides in the corolla. In the Asclepiad, Pentatropis spiralis, green is manifest; but yellow and blue, as normal colours, respectively give out varying tints of white and red, as in Dahlia and Harebell. Yellow and blue, however, are both combined in the Pansy; for each cell enclosing its own matter, the colours are thus shaded on the same leaf.

The higher portion of a petal, broad like a blade, is called the *lamina*, *plate*, or *border;* the lower portion, frequently tapering like the petiole of a leaf, is called *unguis*, or *claw*, Plate IX., fig. 20; and when this latter instrument is absent, as in Rose, the petal is sessile. If the base be attached by an articulation, the petals are caducous or deciduous, according as they fall off after expansion, or after fertilization. When simply continuous with the axis, the base of the corolla usually withers persistently.

The venation of the organ is reticulated either from a median, or from several primary veins. Hence the growth defined by their arrangement occasions the varieties of petals, called *fimbricated*, or fringed, as in Pink; *cuspidate*, terminating in a free point; *cymbiform*, or *navicular* (*cymba*, boat, and *navis*, ship), according to flatness or concavity; *cochleariform*, spoon-shaped; *calcarate*, as in Snapdragon; and *gibbous* (*gibbus*, bunch), or *saccate*, resembling a swelling, as in Antirrhinum. Many other varieties obtain, similar to those already noticed belonging to leaves, as crested, obcordate, bifid, linear, hastate, &c.

The corolla is *unipetalous* when it consists of one petal only, as in the ovate concave of Amorpha. But the petals may be two or more, and then are variously united, as in Gentian and Foxglove. When more than one petal are joined together, the divisions at the apex indicating their number, the corolla becomes very distinct from unipetalous; it is *monopetalous* or *gamopetalous*, Plate VIII., fig. 1, as in Phyteuma, Rampion. The posterior part of such a corolla is generally tubular—hence called the *tube*, Plate IX., fig. 18, *b*; and the upper, or *limb* portion, Plate IX., fig. 18, *a*, seldom entire, is often partially free, as in Perennial Wormgrass. The size of the petals being each equal to another, the corolla is said to be *regular;* if unequal, *irregular.* Regular corollas of this description include the *bell-shaped*, as Campanula, Plate IX., figs. 14—16; *funnel-shaped*, Plate IX., fig. 17, as Tobacco; *salver-shaped*, with the tube surmounted by a spreading limb, Plate IX., fig. 18, as Primula; *tubular*, Plate VIII., fig. 14, as Comfrey; *wheel-shaped*, Plate IX., figs. 21, 22, as Forget-me-Not; stellate, or star-shaped, Plate VIII., fig. 11, as Galium; and urn-shaped, as Five-leaved Heath. Among the irregular monopetals, may be ranked the *labiate*, or lipped, an arch on the upper lid of which renders it ringent, Plate VIII., fig. 4; *personate* (*persona*, a mask), Plate VIII., figs. 7, 8, with a *rictus*, or *chink*, left between the lips, as in Frogsmouth; *calceolate* (*calceolus*, a slipper), when there are two lips of that shape, as in Cypripedium calceolus, Common Lady's slipper; and *ligulate* (*ligula*, a little tongue), Plate VIII., fig. 10, strap-shaped, as in Catananche cærulea, Azure, Lion's-foot. Irregularity among corollas, generally speaking, arises from unequal development of the segments through adhesion or atrophy. It may also take place from angular inclination of the segments, or from a metamorphosis of stamina.

But while, in many species, the petals, being more than one, unite together, they often stand distinct from each other, as in Cinquefoil and the Vine; and the corolla is then rendered *polypetalous* (πολὺς, many). In their separate state, they are, for the most part, verticilately disposed, sometimes continuously spiral with the segments of the calyx, and sometimes circularly alternating with the sepals. There is a *regular* and *irregular* form here also. To the former belong corollas, named *rosaceous*, after the simple rose, containing five spreading petals, without claws; *caryophyllaceous*, five petals, with long tapering claws, as Pink; *alsinaceous*, claw still broader, and petals more spaced, as in Chickweed; and *cruciform* (*crux*, cross), Plate IX., figs. 19, 20, four petals crossed, as in Wallflower. Among the irregular forms of polypetals, stands the *papilionaceous* corolla, Plate VIII., fig. 5, with five petals, the largest called *vexillum*, or *standard*, Plate VIII., fig. 6, *a*, turned over in direction of the axis, associated with two lateral *alæ*, or *wings*, Plate VIII., fig. 6, *b*, *b*, and two anterior petals, forming the *carina*, or *keel*, Plate VIII., fig. 6, *c*, which covers up the more internal organs. The Pea, and other leguminous plants, supply instances.

There is yet another point of interest peculiar to the corolla which deserves mention, before bringing this description of the reproductive organs to a close for the present. The phenomenon refers to the diurnal expansion and closing of flowers, carried on chiefly by the sensitive agency of the corolla. We will not expatiate on the final causes of this appointment, embracing as these do, in favour of each species, a periodical

definition of rest, a more distinct evolution of the elements of smell, and a graduated economy for ocular exhibition. The principle has been happily illustrated by a selection made by the great Swedish botanist, in conformity with the hours of time, and usually called—

Linnæus's Floral Clock.

Yellow Goatsbeard,	Tragopogon pratense,	3—5	A.M.
Smooth Hawkweed,	Crepis tectorum,	4—5	"
Wild Saccory,	Cichorium intybus,	5	"
Dandelion,	Leontodon taraxacum,	5—6	"
Spotted Cat's-ear,	Hypochæris maculata,	6	"
Sow-thistle,	Sonchus cæruleus,	6—7	"
Water Lilies,	Nymphæa and Nuphar,	7	"
Small Cape Marygold,	Calendula pluvialis,	7	"
Scarlet Pimpernel,	Anagallis arvensis,	8	"
Field Marygold,	Calendula arvensis,	9	"
Ice Plant,	Mesembryanthemum crystallinum,	9—10	"
Sandworts,	Arenaria,	9—10	"
Knotted Figwort,	Scrophularia nodosa,	10—11	"
Common Star of Bethlehem,	Ornithogalum umbellatum,	11	"
Many Figworts,	Scrophularia,	12	"
Afternoon Squill,	Scilla pomeridiana,	2	P.M.
Marvel of Peru,	Mirabilis Julaga,	5	"
Sad Pelargonium,	Pelargonium triste,	6	"
Night-flowering Catch-fly,	Silene noctiflora,	8—9	"
Night-flowering Cereus,	Cactus grandiflorus,	10	"

Jean P. F. Richter combines some human contrasts with this horological calendar. "I believe," says he, "the flower-clock of Linnæus in Upsal, whose wheels are the sun and earth, and whose index-figures are flowers, of which one always awakens and opens later than another, was what secretly suggested my conception of the *human clock*. I formerly occupied two chambers in Scheerow, in the middle of the market-place; from the front room I overlooked the whole market-place and the royal buildings; and from the back one, the botanical gardens. Whoever now dwells in these two rooms possesses an excellent harmony, arranged to his hand, between the flower-clock in the garden, and the human clock in the market-place. At three o'clock in the morning, the Yellow Meadow goatsbeard opens, and brides awake, and the stable-boy begins to rattle, and feed the horses beneath the lodger. At four o'clock, the little Hawkweed awakes, choristers going to the cathedral, who are clocks with chimes, and the bakers. At five, kitchen-maids, dairymaids, and Buttercups awake. At six, the Sow-thistle and cocks. At seven o'clock many of the ladies'-maids are awake in the palace, the Chiccory in my botanical garden, and some tradesmen. At eight o'clock, all the colleges awake, and the little Yellow Mouse-ear. At nine o'clock, the female nobility already begin to stir, the Marygold, and even many young ladies, who have come from the country on a visit, begin to look out of their windows. Between ten and eleven o'clock, the Court ladies, and the whole staff of Lords of the Bedchamber, the Green Colewort, and the Alpine Dandelion, and the reader of the Princess, rouse themselves out of their morning sleep; and the whole Palace, considering that the morning sun gleams so brightly to-day from the lofty sky, through the coloured silk curtains, curtails a little of its slumber. At twelve o'clock the Prince, at one his wife, and the Carnation have their eyes open in their flower vase. What awakes late in the afternoon, at four o'clock, is only the Red Hawkweed, and the night watchman, as cuckoo-clock; and these two only tell the time, as evening clocks and moon-clocks. From the hot eyes of the unfortunate man, who, like the Jalap plant, opens them at five o'clock, we will turn our own in pity aside. It is a rich man, who has taken the jalap, and who only exchanges the fever-fancies of being griped with hot pincers, for waking gripes. I could never know when it was two o'clock, because at that time, together with a thousand other stout gentlemen, and with the Yellow Mouse-ear, I always fell asleep; but at three o'clock in the afternoon, and at three in the morning, I awoke as regularly as though I was a repeater. Thus we mortals may be a flower-clock for higher beings, when our flower-leaves close upon our last bed; or sand-clocks, when the sand of our life is so run down, that it is received in the other world; or picture-clocks, because when our death-bell here below strikes and rings, our image steps forth from its case into the next world. On each event of the kind, when seventy years of human life have passed away, they may, perhaps, say, 'What! another hour already gone! how the time flies!'"

Thus, in each flower and simple bell
That in our path betrodden lie,
Are sweet remembrancers, who tell
How fast the winged moments fly.

In the blossoming flower, contemplate, O man! the wisdom and power of the Great Creator. Their hues display the perfection of elegance; their composition the delicacy of infinite care. "Solomon, in all his glory, was not arrayed like one of these." Matth. vi. 29. The tissues and tints of the meanest weed are exquisite, beyond comparison with the finest network of human hands; the pleasure of life arises, in part, from the endless variety which they administer to the eye; they enliven the aspect of nature to the dullest mind, and never cease, to the cultivated judgment, to be objects of quiet interest or intense delight. With what gratitude, then, should the heart glow, at the unsparing munificence which is wreathed around and scattered beneath us, from out of the treasury of God! Let this practical consideration arise to the mind, that, equipped with the charms of piety and knowledge, we shall equally adorn the periods of youth and old age, and, even after death itself, flourish in that better land, where groweth the Tree of Eternal Life.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER III.

Heraclitus of Ephesus, celebrated as the "weeping philosopher," next claims our attention. His first principle and universal agent was fire. Occupying a position midway between the Ionian and Italian schools, he considers the senses as the source of all human knowledge, whilst error springs from the imperfection of our reason. Hence he may be regarded as the type of materialism, sensationalism. He considers all things as in a state of perpetual *flux*, or transition. Nothing *is*, but is always *becoming*, the true conception of nature. Opposite tendencies, in their conflict, are the source of all things—notions which, amidst all vagueness, embody no inconsiderable portion of truth. He leads us, in some degree, to a school whose speculations are of far higher interest than the foregoing, and display a more positive spirit. We mean the atomists, Leucippus, Democritus, Empedocles, and Anaxagoras. Of what, namely, does all matter consist? Is it a homogeneous, continuous mass, capable of expanding and contracting by its own essence; or is it composed of innumerable particles, practically though not conceptionally incapable of further subdivision, and hence called atoms? These philosophers, in opposition to the Eleatics, adopted the latter supposition. Leucippus of Miletus (?) constructs the world of atoms, motion, and a vacuum. His atoms differed among themselves merely in magnitude and figure. The former difference caused the particles to collect round certain centres, whilst the difference of figure led to entanglement and cohesion. Around the centres or masses thus formed, other atoms would gradually cluster, and so matter become condensed in the form of hollow globes. These set in a rotatory motion by other atoms rushing in upon them from without, gradually formed the heavenly bodies; the earth filling the centre of the universe, and the sun and stars revolving round it. He explains how bodies of the most varied properties may arise from the juxtaposition of these atoms, in a manner which seems almost like a foreshadowing of our doctrine of isomerism. He compares elements, alike in number and nature, but differently arranged, to letters, which, accordingly as they are grouped, may produce either a comedy or a tragedy. He gives account of the composition and decomposition of bodies, which, formed by the aggregation of atoms, are again destroyed by their separation.*

* The Hindoo philosopher, Kanadi, had, at a very early period, assumed the existence of atoms, which he whimsically estimates to be equal in size to the sixth part of the motes in a sunbeam.

Democrites of Abdera,* known, in opposition to Heraclitus as the "laughing philosopher." His memory also has been obscured by fabulous tradition, and historians have ranked him among various philosophic sects. Developing the doctrine of Leucippus, he ascribed to his atoms, gravity, which, however, plays no part in his system. He attributes to some atoms an inherent principle of vitality. Their motions he considers to be of two kinds—a perpetual descent, arising from their weight; and a rebound, from contact. In astronomy also he made some advances, and declared the true nature of the "milky way."

Empedocles of Agrigentum, in Sicily, like Pythagoras, has been made the object of superstitious reverence. He is said to have wrought miracles, to have predicted and even influenced the weather. His knowledge of natural history and meteorology was extensive, and his death in the crater of Etna may have occurred, not intentionally, but from his prying too closely into the phenomena of an eruption. He first, it appears, introduced the doctrine of the four elements, so universally adopted in antiquity, out of which all things were compounded. Still he did not, like his successors, regard these as primarily distinct in their natures, but as mere modifications of the first matter, types of its different forms of existence, or, in the language of our own times, states of aggregation. His earth, is the solid; his water, the liquid; his air, the gaseous; and his fire, the not yet defunct phantom of the imponderable. In his hands, therefore, the doctrine of the four elements was a far more philosophical conception than it became among subsequent imitators. The mutual combinations and decompositions of his elements, he ascribes to two opposite principles, love and hatred, or, as we should say, attraction and repulsion. From Leucippus and Democritus he differs, by considering matter as infinitely divisible, and by denying the existence of a vacuum.

Anaxagoras, of Clazomenæ, is known in history as the preceptor of Pericles, Euripides, and Sophocles, and as one of the earliest martyrs of philosophy. Even in Athens, that sanctuary of intelligence, envy and bigotry were not absent. The philosopher was condemned to death on the usual intangible, and therefore convenient charge of impiety, and all the influence of his friend and pupil, Pericles, availed no farther than to commute his sentence to banishment. He retired to Lampsacus, and ended his days in peace. Instead of admitting, with the Ionians, one elementary matter, Anaxagoras assumed distinct particles for every kind of substance (homoiomeriæ). He maintained that air comprised the elements of all living beings, and that these were introduced into plants by means of water.† He explains the formation of animals and plants, and the phenomena of the heavens, in a manner more tangible and less metaphysical than was customary among the Greeks. Hence his doctrines were despised by word-splitters, for what, in reality, constitutes their excellence. The atomists constitute a remarkable phase in the history of the Greek intellect. Free to a great extent from the supernatural tendency, and even from the metaphysical speculations common among their countrymen, they set a higher value upon observation and experiment, upon a patient practical study of nature; and in so far they manifest clearly the elements of positivism. The ideas of force and matter, of attraction and repulsion, of composition and decomposition, perhaps, even, of polarity, begin to appear in their speculations. Had the impulse they gave been followed up, much that has been reserved for our days might have been anticipated. But the attempt was premature. The Greek impatience of detail, its love for abstract *a priori* speculation returned, and the atomists could but bequeath to mankind a prophecy whose fulfilment was far distant.

With the development of the metaphysical system, and the gradual elimination of the sciences fromunder its sway, the history of Greek speculation becomes, for our purpose, less important. Socrates concerns us mainly as having operated a separation—provisional, indeed, but not the less necessary—between physical and moral philosophy. That, in the end, all science must become physical, is here nothing to the purpose. In so doing, he obeyed instinctively a necessity which became yet more striking in the following ages. Science was not yet able to attempt a physical solution of mental and social phenomena, and, on the other hand, the metaphysical and supernatural conceptions of the ruling philosophy could no longer embrace the sciences. For the development of both, a separation, therefore, was then required, just as the present age emphatically demands a reunion. Socrates, in early life, gave his attention to physics, but afterwards confined himself to morals. Proclaiming man as the great object of study, he did not perceive him to be necessarily the last, as the most complex. It is sometimes erroneously asserted that Socrates proceeded by induction, and so anticipated the great Baconian reform. But the induction of Socrates was a mere reasoning from analogy, a bare enumeration of particular facts. Now such induction, *per enumerationem simplicem*, Bacon condemns as fallacious, and points out a more satisfactory procedure. Furthermore, Socrates endeavoured with all care to withdraw men's attention from outer nature, and fix it upon the workings of their own minds. Bacon laboured in the opposite direction, abandoning psychology as a problem for the present at least insoluble. The war waged by the former against the sophists, and by the latter against the schoolmen, is the only point of resemblance. It is unjust, therefore, to assume with Coleridge, that Sócrates and his disciple Plato have in any way anticipated Bacon.*

We glance now briefly at the place filled by Socrates in the martyrology of the intellect. He was a reformer, and where he saw error, attacked and exposed it—a course as invidious in ancient Athens as in our generation. Political considerations supervened, for he taught that government is a science, or, at least, the application of a science, and cannot be intrusted with safety to every ignorant pretender. The charge of impiety, heresy, is again brought forward. His trial, condemnation, and death, are too well known to require notice.

Plato, the disciple of Socrates, gave, like his master, little attention to positive science. He divided philosophy into logic, physics, and morals; discriminating between the analytical and the synthetical modes of investigation, and attaining clearer views than his predecessors on the laws of thought, on cause and effect, on the faculties of the mind, which he endeavours to define and separate. For the universe, he accounts by the aid of two principles, ideas and matter. Under the latter term he understands a something, in itself destitute of all properties, but capable of having them impressed upon it from without. By ideas he denotes certain archetypes, or models, pre-existing in the divine mind, and superinduced upon matter. He considered, therefore, general terms, the names of classes, as something actually existing, not as mere abstractions of our own minds. Thus he would, besides all individual stones, assume the existence of an archetypal, model stone, and that the former were stones only in as far as the properties of the latter inhered in them. He was thus the founder of realism, which we shall find very prominent in a subsequent epoch. He considers matter as infinitely divisible, but adopts the doctrine of the four elements, and even speculates on the figure of their particles. He considered the universe, in its totality, as animated. He supposed the centre of the earth to contain streams of fire, the cause of volcanoes. He had a clearer notion of gravitation than his successor, Aristotle.

With the sects of Stoics, Cynics, and Sceptics, we need not concern ourselves; they added nothing to our knowledge of the universe, and the jargon of their disputes, its aim being fulfilled, may be allowed to die away in the distance. The results of Greek philosophy may be regarded as summed up in Aristotle. Born at Stagira, in Thrace, he removed to Athens, and attended the school of Plato. He next repaired to the Macedonian court, to superintend the education of the young prince, Alexander. Afterwards he returned to Athens, and opened a philosophical school in the Lyceum, lecturing in the morning to his more advanced pupils, and in the afternoon to a promiscuous audience.

* The Abderites were famed for their stupidity. That a Democritus should arise among them was no less marvellous, than if in our days a great philosopher should spring from Pomerania, La Vendée, or Dorsetshire.

† This agrees tolerably well with our modern knowledge, since we know that plants and animals are mainly composed of oxygen, hydrogen, nitrogen, and carbon, or, as Dumas expresses it, "plants and animals proceed from the air and return thither; they are products of the atmosphere." The doctrine of the homoiomeriæ, every substance being nourished by absorbing particles similar to itself, may be compared with the views of Liebig and Mulder on the nutrition of animals.

* Coleridge, Treatise on Method, p. 46.

His attention was mainly directed to the laws of thought, and to the elaboration of logic, of which he may be considered as the father. He first ascertained the laws of the syllogism. Laying more stress upon experience than does Plato, he proclaimed the ideas of the latter to be mere logical abstractions, devoid of objective existence.* He, and not Plato, was on the point of anticipating Bacon. He says, "art † commences when, from a great number of experiences, one general conception is drawn which will comprehend all similar cases." In these words, mankind approaches the very boundary of positivism, its land of promise; but recoils again, like Israel of old into the desert. As regards method, Aristotle fell little short of Bacon, but he sinned against his own method. Proclaiming that experience was the great guide to truth, nay, that it could not mislead us, he yet, in practice, adhered to the old Greek custom of analyzing words instead of things. Not, indeed, but what he amassed, from books and from nature, a vast amount of knowledge, and attained glimpses of the most important truths. His classification of animals was a noble achievement; he preserves a clear view of the essential unity of nature throughout his speculations. Yet he still seeks after first and final causes, and inquires into the essential properties of things —questions utterly foreign to true philosophy. In his political writings, he not only upholds slavery as justifiable, but cannot conceive a state existing without it—a remarkable proof how much even the greatest minds are modified by the age in which they live.‡ Of the influence subsequently attained and exerted by Aristotle during so many centuries, we will speak below.

After the epoch of Aristotle, the separation between "moral" and "natural" philosophy initiated by Socrates, grew continually more decided. The philosophers, as they continued to be called, wandered through all the mazes of metaphysical subtlety, proving nothing except the utter hopelessness of their own object. On the other hand, men arose, devoted to the pursuit of some single branch of science, as mathematics, or astronomy, or of art, as medicine, who, whilst making no claim to the rank of philosophers, gradually laboured at the foundations of positive truth. Before adverting in detail to the career of these men, we will inquire into the general failure of Greek philosophy. Were they deficient in acuteness, in grasp of intellect? By no means, their very failures bear ample testimony to their exalted mental endowments. The cause is this: they pursued a wrong object, and employed a false method. To their error in the former regard, we have already alluded. In the spirit of the metaphysical era, they sought to know, not merely *phenomena*, the properties of things (or rather their effect upon our organs of sensation), but *noumena*, the essence of the things themselves. They inquired into origins and purposes, into first and final causes, putting the question 'why' instead of 'how.' They thus mistook the very nature of scientific explanation. And their error in point of method was no less dangerous. Proceeding from the point of view common to the supernatural and metaphysical periods, they regarded man as the rule of all things. Hence his conceptions, and the words by which these are expressed, became the subject of their analysis, to the neglect of things in themselves. Knowing in general no language but their own, they could not free themselves from the notion, that whatever happened to have a common name in Greek must have a common nature.§ Little argument is required to show the utter fallaciousness of such a procedure. Take the name of a plant or a mineral, and try how many of its properties, physical, chemical, or physiological, you can ascertain from the most acute examination of the word. In the best case, no more than was known by the man who first gave the name. But before we pass uncharitable remarks upon the Greeks, let us bear in mind that this error, though universally scouted in theory, is widely upheld in practice. Without constant and jealous scrutiny, we are still apt to make our own language, and its incidental classifications, the rule and measure of existence. Great weight was laid by the Greeks upon the doctrine of contrarieties; the antitheses of common language must, they imagined, necessarily shadow forth some corresponding contrast in the objects or properties designated. Thus, according to Aristotle, the Pythagoreans collected ten principles—finite and infinite, odd and even, one and many, right and left, male and female, rest and motion, straight and curved, light and darkness, good and evil, square and oblong. This, then, was the main fundamental error of the Greek philosophy. It sought, with few and transitory exceptions, an object essentially unattainable; and, with exceptions no less rare, it employed a false method, seeking for truth in words and notions, rather than in things. It might even be suggested that the very exuberance of intellectual life among the Greeks, perhaps, proved detrimental to their scientific progress; just as crops sown upon a field too richly manured, shoot up into rank foliage, but yield little fruit. With a youthful impatience, they sprang forwards at once to grasp results, impatient of preliminary details. Hence, when we weigh, measure, or count, they were satisfied with guessing. An ingenious and plausible theory had for them such charms, that its verification was rarely attempted.

But though admitting its failure, we must still allow the Greek philosophy no mean value. If the thinkers of Athens failed to solve the great problem of existence, they ascertained, at least, the nature and extent of the human faculties. It is by their example that we have been taught a better method. For the records of failure are no less valuable than those of success. What would have been our present position had they not gone before us as the forlorn hope of the world? Their short-comings were not blameworthy, avoidable; they were the necessary features of the chrysalis state of humanity. Let us not exult over them, for our transformation is not yet complete. The wings of Psyche are still entangled in the cerements of the past.

Let us now notice the development of the various sciences, as they one by one detached themselves from the primitive philosophy, and took up an independent position. Mathematics led the way. The phenomena of number and magnitude, from their universality, could not escape attention, and from their simplicity, must earlier admit of true scientific treatment. The fondness of the Greeks for deductive speculation was here less prejudicial than in other departments, for in mathematics the province of induction is so limited as to have escaped the notice of most authors. We have already alluded to the researches of Thales and Pythagoras, the latter of whom displays the curious phenomenon of numerical mysticism. This tendency, however, soon vanished, and questions of magnitude and number were treated by the Greeks in a true positive spirit. The department most cultivated was geometry. Pythagoras first gave it a methodical form; after which it was cultivated by Anaxagoras, Œnopides, Hippocrates of Chios, Theodorus of Cyrene, Plato, Leodamas, Archytas, Neoclides, and Leo. The discoveries of these were combined into a complete system by Euclid of Alexandria. The current story of geometry being of Egyptian origin, and thence transmitted to Greece, is in itself highly improbable, and clashes with several established facts. Whatever amount of mathematial knowledge oriental nations may have possessed, the Greeks appear to have developed the science without foreign assistance. Arithmetic and algebra were less cultivated by the Greeks than the Hindoos, from whom our present system of numerals (erroneously called Arabian) is derived. The application of algebra to geometry, which has led the way to so many astonishing results, is of later date.

Next in order of antiquity, as well as of generality and simplicity, stands astronomy, a science constituted at a very early period, and attentively studied by the Greek sages. During its supernatural and metaphysical periods, it appears as *astrology*, which we shall notice at length in treating of the philosophy of

* The reader may be reminded that, in the language of metaphysicians, *subjective* is applied to whatever exists within the mind; *objective* to the outward bodies which it contemplates.

† The terms 'art' and 'science' were used indiscriminately until a very recent epoch, and are still confounded by careless writers. Thus we hear tell of the 'sciences' of navigation, horsemanship, elocution, penmanship, and even, *proh pudor!* foxhunting.

‡ Slavery, we must remember, when first instituted, was, undoubtedly, a step in advance. The previous fate of the vanquished had been indiscriminate slaughter. Modern colonial slavery is, undoubtedly, a practical anachronism.

§ Thus the diversity of tongues however, much regretted by semi-philosophers as impeding intercourse between nations, has played a most important part in the education of the human race. Had only one language existed, we might never have been able to free ourselves from verbalism.

the middle ages. The history of astronomical science having been already given in this work, we refer the reader to Vol. I., pp. 250, 384, 436, and 635.

More complex, and developed at a somewhat later date, comes physics, the least inwardly coherent of the sciences. Its first subdivision, *barology*, which, confounded with that part of mathematics treating on motion, is commonly called "natural philosophy" or "mixed mathematics," took its rise next in order of time to astronomy. We must, in fact, regard it as the application of the great laws of astronomy to terrestial objects. Mankind could not long exist upon the earth without becoming empirically acquainted with the phenomena of weight and pressure. But though a tacit knowledge of mechanical laws was involved in the arts of remote antiquity, and though, as we have already remarked, mankind never deified weight, still the science was not definitively constituted before Archimedes of Syracuse. This great man established the doctrine of the lever in a truly positive manner, proving that bodies are of equal weight which balance each other at equal arms of a straight lever, and that there is, in every ponderable body, a certain point or centre of gravity, where the whole weight may be assumed to be collected. He solved also the conditions under which bodies float in any liquid, and established the proposition known as the hydrostatic paradox. He comprehended the fundamental idea of fluids, as bodies whose parts are perfectly moveable among themselves, and in which all pressure exerted on any one part is equally transmitted to all other parts.

In optics the Greeks made but little advance. They had mastered the law of reflection, but of refraction their notions were very indistinct. They supposed that vision depended on rays proceeding, not from the object to the eye, but from the eye to the object, with which the former gropes out the form of the latter. Aristotle, admitting the existence of light as a medium between the eye and the object, proceeds to define it as "transparency in action;" darkness is transparency potential, but not actual. Colour is not the "absolute visible," but something superimposed which has the power of setting the transparent in action.

In acoustics, a correct foundation was laid at a remote period. The origin of sound is a motion of the sonorous body, and its transmission to the ear by some motion in the atmosphere was admitted by the earliest speculators; but beyond this primary fact no advance was made for a considerable period.

Thermology, the doctrine of heat, made little progress until a comparatively modern period. The Greeks accounted for the phenomena of heat by their element of fire. Electricity and magnetism can scarcely be said to have had an existence. The facts that the loadstone attracts iron, and that amber when rubbed exerts a like influence upon straws or other light substances, were known and commented on, but no step was taken towards a correct explanation of these phenomena. Chemistry had no existence, save in those notions on the molecular constitution of matter embodied in the general philosophy of the period which we have already mentioned, and in the processes empirically followed in the arts. Physiology (more correctly, biology), though still from its complexity in so backward a state, became the object of speculation at a very early period. Hippocrates, the earliest medical writer, shows a considerable knowledge of the general structure of the human frame, though he fails in clearly distinguishing the nerves from the muscles.* On the subjects of digestion, assimilation, reproduction, and the functions of the nervous system, nothing was attained beyond crude guesses and unfounded generalities, whilst the highest part of the science lay entirely out of sight.

Whether the disputed sub-science of mesmerism (animal magnetism, tellurism) was known at this period, has been a subject of discussion.† By some it is identified with the ancient magic, and viewed as the key to the temple-sleep of the Egyptians and the oracles of the Greeks.‡

To the theories held by the Greeks on psychology we have already alluded. They anticipated all the various shades of opinion held by more recent metaphysicans. They made a distinction between soul and spirit. The immortality of the soul was first taught by Pherecydes. Others, again, adopted materialist views, and derived thought and emotion from the arrangement of atoms. It is remarkable, that the remains of Greek art betray what might be called a latent knowledge of phrenology, the structure of the head being in general what a professor of that science would assign to the character intended to be delineated.

With the fall of Greek independence, the intellectual activity of Athens gradually declined, or was diverted to less important objects. Verbal quibbles and niceties of style attracted the attention of the learned, in place of the great problems of the universe, and the Greek philosophy of succeeding ages amply merits the severest censures passed upon it by Bacon.

CONCHOLOGY.

CHAPTER III.

Genus.—Ammonites.—*Lamarck.*

Generic Character.—Shell discoidal, multilocular; volutions contiguous, all of them visible to a greater or less extent, gradually and spirally coiled around the first or central one, so as to exhibit each volution increasing progressively in size outwardly, and more or less compressed; inner partitions articulated by sinuous sutures; septa transverse, lobed at the circumference and imperforated at the disc, but perforated by a single tube or siphuncle, situate near the outer margin or back of the shell; aperture in most species thickened, expanded outwards in some, and in others contracted.

Ammonites giganteus. Plate III. fig. 8.

The situation of the siphuncle is a very decided character in this genus. It is invariably placed in the aperture, close to the dorsal margin or ambit, penetrating the transverse partitions, as exhibited in Plate I. fig. 4. It is represented in black, and marked by the letters *c, d, e, f, g, h*. It is conducted through the septa by a ring projecting outwards, and may be traced penetrating through the whole transverse partitions, or plates, of the figure above referred to. In most of the carinated species, the siphuncle is placed in the keel; while in the genus *Nautilus*, the siphuncle is either in the centre of the convolutions, or towards their inner sides. The body of the animal has occupied that portion of the shell from *a* to *b* in *A. obtusus*, Plate I. fig. 4.

The delicate dorsal siphuncle of the Ammonite is not sufficient to prevent concussion of the animal within its partitions. Other means of attachment are accordingly necessary, and the following provision is found. Below each partition there lie six lobes, symmetrically arranged around the circumference of the shell. The first, or *ventral* lobe, is usually the most considerable, and rests upon the back of the convolution which precedes it. On the opposite side, the dorsal lobe advances itself towards the bottom to embrace the siphuncle, and it is thereby divided into two cones, which are more or less separated from one another. At one-third the height of the aperture from the back, the *superior lateral lobes* are placed on each side, and lower down the *inferior lateral lobes* are similarly arranged, the latter being a little more elevated than the ventral lobe. The separations of these lobes form the *sellæ*, or seats, so termed because the animal rests upon them, and their distinctive names are derived from those of the lobes.

* To him belongs the merit of having first separated medicine from general philosophy, and asserted its distinct nature, a step evidently showing an advanced insight into the mutual relations of science and art.

† This is evidently not the place to enter upon the mesmeric controversy. That there are phenomena, partly physical and partly physiological, not yet incorporated in our authorized systems of science, is undeniable. But that the true appreciation of these phenomena has been very much retarded by quacks and impostors, must be owned with regret. What can be expected for science from men who speak of "*biologizing*" a person, or who, like the American Stone, reason thus:—"Since I can (temporarily) paralyze the limbs of the subject before you, *it follows* that I can restore, in like manner, the limbs of a man suffering from natural paralysis." To lecture on such subjects to a promiscuous audience, ignorant of the very rudiments of physiology, and of the nature of evidence altogether, is as grievous an absurdity as were we to harangue on the differential calculus to boys who had not yet mastered the elements of arithmetic.

‡ Hippocrates, *De Insomniis.* Plutarch, *De Iside et Osiride.*

Some of the Ammonites are plain, but most of them are variously sculptured, and many are annulated like a ram's horn, from which circumstance, in all probability, they have their common name, *Cornua Ammonis*, or Ammon's Horn; Jupiter being worshipped by the Egyptians under the name of Ammon, a deity represented by the ram. The whole of the ancient sculptural representations of Jupiter have invariably ram's horns, as also those of Alexander the Great, after he was deified as the son of Ammon.

A superstitious belief prevails in England that Ammonites are petrified snakes, founded, no doubt, upon a legend in Camden's Britannia, which is thus recorded:—"Upon the same river Avon, which is the boundary here between this county (Somersetshire) and Gloucestershire, on the western banks of it, is Cainsham (now Keynsham), so termed from Keina, a devout British virgin, whom many of the last age, through an over-credulous temper, believed to have changed serpents into stones, because they find sometimes in quarries some such little miracles of sporting nature. And I have seen a stone brought from thence, winded round like a serpent, the head whereof, though but imperfect, jutted out in the circumference, and the end of the tail was in the centre, but most of them want the head."

This is a most comprehensive genus, consisting of shells found only in a fossil condition. It is a remarkable circumstance, that not a single type of this extensive family exists in the present seas of our globe. In Great Britain and Ireland alone, 184 species have been ascertained and figured.* They occur in all formations from the Transition strata, and disappear with the termination of the Chalk. Besides those which are met with in the strata of Britain, there are numerous other species differing entirely from them, which occur in various quarters of the globe. M. Brochart has enumerated *two hundred and seventy species*. These Ammonites differ according to the age of the strata in which they are imbedded, and vary in size from an eighth of an inch to more than four feet in diameter. One of the earliest forms of this genus is the *A. Henslowi* (now *Goniatites Henslowi*), Plate III. fig. 7, which is lost with the Transition series. The *A. Nodosus*, Plate III. fig. 17, is peculiar to the Muschelkalk. Other Ammonites appear only in certain definite strata of the Cretaceous or Oolitic formations. *A. Bucklandi*, Plate III. fig. 13, occurs only in the Lias, while *A. Goodhalli*, Plate III. fig. 12, is peculiar to the Greensand, and *A. rusticus*, Plate III. fig. 16, is met with only in the Chalk. There are no single species which run through the secondary periods, or which have passed into the Secondary from the Transition formations.

Mr. Phillips gives the following distribution of Ammonites through the various geological formations. None have been found in the Tertiary series; in the Cretaceous series, 45; in the Oolitic series, 137; in the Saliferous series, 15; in the Carboniferous series, 7; and in the Primary, or those strata which are included in the lower regions of the Transition series, 17: making a total of 223 species. These he divides into sections, or sub-genera. "It is easy to see," says he, "how important, in questions concerning the relative antiquity of stratified rocks, is a knowledge of Ammonites, since whole sections of them are characteristic of certain systems of rocks." † But recent discovery has considerably increased those numbers.

The shells of this genus have greatly perplexed conchologists and geologists, as they have never been able to account for their use and plan. Impressed by the analogies presented by the genus *Spirula*, Plate I. fig. 27 (a genus known only in a recent state), Lamarck and Cuvier considered them to be *internal* shells; that is, enveloped within the body of the animal. Cuvier was led to this conclusion from the smallness of the outer chambers. But this theory seems to have been founded on observations made on imperfect specimens. When the outer chamber is obtained in its perfect condition, it is found to be as large in proportion as the outer cell of *Nautilus Pompilius*, Plate I. fig. 3, is to the chambered convolutions of that shell.

* See Brown's Illustrations of the Fossil Conchology of Great Britain and Ireland, Plates IV. to XX.

† Phillips' Guide to Geology, 1834, section 82.

It will be seen by our section of *Ammonites obtusus*, Plate I. fig. 4, that it often occupies nearly half the circumference of the outer volution, from *a* to *b*; and in other instances it embraces nearly the entire outer volution, as represented from *b* to *i*. Unlike the thin fragile exterior chamber in *Spirula*, that of the Ammonites is nearly as thick and strong as the close-chambered portion.

Besides what we have above shown, the spinous exterior of many of them, such as *A. Gowerianus*, *armatus*, &c., presents a striking argument against their being internal shells; as those processes, which seem to be destined as a protection to the animals against their enemies, would not only be useless, but irritating to the soft integuments of a mollusc.

Ammonites giganteus. Plate II. fig. 8. Found in sandy limestone, in Chicksgrove quarry, near Hindon, Wiltshire; it has also been met with at Purbeck Isle, Dorsetshire, Marlborough Downs, and in the Chalk, near Margate. It is one of the largest of the genus. There is a specimen in the *Jardin des Plantes*, Paris, which measures four feet in diameter. We have given a representation of the winding partitions which intervene between the air chambers of *A. giganteus*, Plate I. fig. 1.

A. heterophyllas, Plate I. fig. 17, from the Lias at Whitby. It is a longitudinal view of the fossil. The transverse plates, which approximate so closely on the sides of the shell, where it is flat and weak, are seen to be distant from each other along the dorsal region, which is strong from its convex form.

The small circular black spot marked *a*, is the siphuncle; *b*, the dorsal lobe; *c*, the dorsal saddle; *d*, the superior lateral lobe; *e*, the lateral saddle; *f*, the inferior lateral lobe; *g*, the ventral saddle; *h*, ventral lobe; *i i i*, axillary lobes. The situation in which the siphuncle passes through the partitions is represented in Plate I. fig. 19, *c*.

It has been demonstrated by De La Beche, from specimens obtained in the Lias at Lyme Regis, Dorsetshire, that the entire body of the animal was contained within the outer chamber; and that these molluscs must have been suddenly annihilated, and entombed in the earthy deposit of which the Lias is composed, before their bodies had been affected by decomposition, or had been devoured by the crustaceous carnivorous animals which abounded in the former ocean.

There is considerable difficulty in the discrimination of species of the genus *Ammonites*, as many of them differ very materially in their progress from their infant to their adult condition.

In the *Goniatites sublæves*,* there is a great dissimilarity of form between the young and old shells. In the infant state, when the shell is a quarter of an inch in length, it is only half that breadth, and is provided with distinctly-marked transverse small ribs; as the shell advances in size, these become more rounded and obtuse, and are alternately long and short, and some of them furcated. When it has reached the length of from two and a half to three inches, these ribs become almost obsolete, and when the shell has acquired its full growth of four or five inches, they can be traced with the utmost difficulty, and sometimes are invisible; and the shell has become almost spherical.

In carefully tracing its progress, it will be observed that the chambers become more deep and quadrangular, thus producing a new external contour in the shell.

To elucidate this subject still farther, we have given a representation of *Ammonites Murchisonæ*, Plate I. fig. 18. It will be noticed, that the inner volutions in the infant state, as seen in the innermost volutions, are smooth; and afterwards, in the young condition, the volutions are crossed by pretty strong, curved ribs, which are somewhat irregular in their degree of elevation. These continue until the shell has reached the diameter of about two inches, when they very suddenly become plain, exhibiting only transverse and slightly-waved lines of growth.

Ammonites seem not to have been subjected to the same laws of geographical distribution as other animals which existed along with them in the ancient world, for we find them

* Brown's Illustrations, Foss. Conch., Plate XVI. fig. 6.

widely spread in almost every country of the globe—the same species in strata of the same age, extending throughout Europe, Asia, and North and South America. Dr. Gerard detected, in the year 1830, at an elevation of 16,000 feet, at Thibet, in the Himalaya Mountains, specimens of *Ammonites Walcotii*, Plate III. fig. 11, and *A. communis*, which were identically the same with those found at Lyme-Regis in Dorsetshire, and Whitby, Yorkshire. The former of these species also occurs in the Lias of Normandy and South of France, Befort, Haut Rhin, Boll, and Ackelberg, and also in the Oolitic group of strata. The Greensand of New Jersey, like that of England, contains Ammonites, Hamites, and Scaphites. Captain Beechy and Lieutenant Belcher detected Ammonites on the coast of Chili, in lat. 36° S., in the cliffs near Conception.

This former universal diffusion of identical species in organic life, differs remarkably from the existing distribution of animals and plants; for we find the geographical range of species limited with astonishing exactness to certain parallels. Hence it seems certain, that during the Secondary and Tertiary periods, a more general diffusion of the same species prevailed than at present, through regions of the world most remote from each other.

Naturalists have divided the Ammonites into several subgenera, depending chiefly upon their external form being more or less globular, the structure of their spiral convolutions being furnished with single, double, or quadruple carinæ; and their external surface being knobbed, ribbed, or plain; but these are not so much to be depended upon as the sinuosity, number, general structure, and distribution of the septa.

Genus.—Endothyra.—*Phillips.*

Generic Character.—Shell involute, discoidal, internally concamerated, the chambers communicating by a large perforation; the septa arranged in stellated order; their emarginations on the inner part of their disc; destitute of any shelly siphuncle. Form of the septal edge unknown. Size one-fiftieth of an inch.

Endothyra Bowmani. Plate III. fig. 15. Found in the Mountain Limestone of Westmoreland.

TRIBE II.—NAUTILACEA.

Shell disciform, with a central spire and short cells, which do not extend from the centre to the circumference.

Genus.—Nautilus.—*Linnæus.*

Generic Character.—Shell suborbicular, multilocular, convolute, with contiguous volutions and simple partitions; septa transverse, and externally concave; perforated in the disc; margins entire; aperture ample.

Nautilus striatus. Plate III. fig. 18.

This genus contains numerous fossil species, and there are two existing ones in tropical seas. The fossil Nautili afford an excellent example of the limitation of certain species to particular geological formations. The *N. multicarinatus* is confined to strata of the Transition series; the *N. bidorsatus* to the Muschelkalk; the *N. obesus* and *lineatus* to the Oolite series; *N. elegans* and *undulatus* to the Chalks; and the divisions of the Tertiary formations contain also species of Nautili peculiar to themselves.

On a careful review of all the fossil Nautili, and a comparison with the only two existing species of this genus, it will be found that they have retained, through strata of all ages, their primitive simplicity of structure down to the present time. They were among the earliest inhabitants of the ancient seas of our globe, and have preserved their generic distinctions through all the revolutions to which the earth's surface has ever been subjected, while its kindred multilocular genera have become entirely extinct. This is the more remarkable, as there are not exceeding sixty species of Nautili, while, it will be seen, upwards of two hundred and seventy species of fossil Ammonites have been ascertained, not a single one of which has survived the wreck of the former world, nor does a type of the genus now exist.

We must explain the functions of this genus of Molluscs by a reference to one of the only existing types, the *Nautilus Pompilius.* Plate I. fig. 3.

The only organ connecting the air chambers with the body of the animal is the siphuncle, which penetrates the aperture, and the short projecting tube, *c*, running through each successive partition, till it terminates in the innermost chamber of the shell. By means of this mechanism, the animal can either augment or diminish its specific gravity, on the same principle as fishes distend or collapse their air bladders; so that when the siphon is filled with water, the entire body is rendered specifically heavier than the surrounding fluid, and consequently sinks: when the water is expelled, it naturally rises to the surface and floats.

The Rhyncholites, or Beakstones, found so plentifully in the Oolite of Stonesfield, the Lias at Bath and Lyme-Regis, and in the Muschelkalk at Luneville, are the fossil beaks of Nautili and Ammonites. (See Plate I. fig. 5.*)

The animal resides in the outer chamber only, and when too large for it a new partition is formed, of dimensions sufficiently ample to accommodate the inhabitant, and thus its former abode is converted into an additional air chamber. We have represented a cast of an air chamber, Plate I. fig. 11.

There is a beautiful contrivance in the shells of this genus, for increasing their strength, and enabling them to withstand the pressure of the fluid by which they are surrounded; namely, the *external* transverse lines of growth or ribs (as in Plate III. fig. 12), having a different curvature from the *internal* transverse plates or partitions; the internal partitions being convex *inwards*, while the outer ribs of the shell are convex *outwards.* These ribs intersecting the curved edges of the transverse partitions at a number of points, naturally divide them into a series of curvilinear parallelograms; the two shorter sides of each parallelogram being formed by the edges of transverse septa, whilst its two longer sides are formed by segments of the external ribs and striæ, or the lines of growth.

In these fossil Nautili, which had not been fractured in the catastrophe by which they were overwhelmed, and the hydraulic actions of the siphuncle not having been effected, the air chambers are generally filled with calcareous spars, which appear to have been subsequently introduced by infiltration of water, holding in solution carbonate of lime, after the animal matter of the shell had been decomposed. In other cases, where the siphuncle had been broken, or the external shell fractured, the chambers are filled by the mud or limestone in which they were embedded.

Two new genera have been proposed, as connected with Nautilus, viz.—

Genus.—Endosiphonites.

A discoidal nautiliform shell, with the siphon situate close to the body volution, which constitutes its chief distinction from Ammonites.

Endosiphonites carinatus. Plate III. fig. 20. Found in the Cambrian strata, Cornwall.

Genus.—Simplegus.—*Blainville.*

Discoidal and multilocular, with the spire uncovered like the Ammonites, but having the chambers divided by simple septa, as in Nautilus.

Simplegus sulcata. Plate III. fig. 22.

Genus.—Nummularia.—*Lamarck.*

Generic Character.—Shell lenticular, disciform, or thick in the middle, and attenuated towards the margin; spire internal, multilocular, covered over by several tables; volutions generally numerous, sometimes to the number of twenty; the outer wall of the volutions complicated, extending and uniting on each side at the centre of the shell; cells very numerous, small, alternate, and formed by transverse imperforate septa, which are convex near their fronts, leaving a fissure between each of them and the preceding volutions; their sides are narrow, variously curved, and extending to the axis.

N. rotulata. Plate III. fig. 21. This species is found at Meudon, France, and is a member of the genus *Lenticulina*, now united to this genus.

* For a minute detail of the construction of the shell of this animal, see the admirable "Memoirs on Nautilus Pompilius," by Professor Owen.

Nummularia lævigata. Plate III. figs. 24 and 25.

There are but few species of this genus, and these are chiefly found in the *Calcaire Grossier.* They have a very wide geographical range, having been met with in France, Germany, Switzerland, Spain, Egypt, and England. We have, however, but four species. *N. lævigatus* is peculiar to the London clay, was first met with in Stubbington Cliff, and has since been found in Bricklesom Bay, Sussex. The *N. elegans* occurs at Emsworth, near Chichester, in a siliceous stone, associated with other extremely minute species of shells. The *N. variolaria* is found abundantly in the London clay, at Stubbington; and *N. Comptoni* has been found at Earlstoke.

Following the idea of Sowerby, we have united the genera *Nummulites* and *Lenticulina,* under the appellation of *Nummularia,* containing some recent species, as the two distinguishing characters of Lamarck are common with the genera, but were overlooked by Sowerby. The small fissure between the edge of each septum and the margin of the preceding volution, as also the small columns which penetrate the parallel axis from one side to the other, and which sometimes form protuberances upon the surface, prevail in both genera. The volutions present the appearance of having been completed, at different periods of growth, by three or four chambers gradually diminishing from the centre, until the last one extends only to the margin of the preceding volution; and the chamber being closed by a convex septum, without a continuous margin, is not so easily detected in such species as have very small chambers in proportion to their diameter, as is the case with most of the Nummulites.

The want of a large external chamber has led naturalists to suppose that the shells of this genus were entirely enveloped in the integuments of the animals while in a living condition; and this idea is further strengthened by no siphuncle having hitherto been detected in these fossils.

The ancients considered Nummulites as petrified lentils. Strabo mentions a species which was found in Egypt near some of the Pyramids.

TRIBE III.—ORTHOCERATA.

Shell not spiral; straight, or nearly so.

Genus.—Conilites.—*Lamarck.*

Generic Character.—Shell conical, straight, sligntly inflated, having a thin external crust distinct from the nucleus or alveole which it contains; nucleus multilocular, divided by transverse septa, which are somewhat separable.

Conilites pyramidata. Plate III. fig. 27.

This genus is distinguished from *Belemnites* by its sheath being thin, and not filled up with solid matter from the point of the nucleus to the apex of the sheath, as in *Belemnites.*

Genus.—Conularia.—*Miller.*

Generic Character.—Shell conical, straight, or nearly so, hollow, multilocular, divided by transverse imperforate septa; aperture half closed by an inflation of the lip; apex solid, obtuse; external surface covered with fine striæ.

Conularia teres. Plate III. fig. 35.

Two species only of this exclusively fossil genus are known. The *C. teres* was found at Troutie Bank, near Glasgow; the other, *C. quadrisulcata,* has been found in ironstone nodules in the Carboniferous Limestone in Renfrewshire. Ure, in his history of Rutherglen and Kilbride, says—" It (the former) is sometimes found enclosed in ironstone like a nucleus; at other times found among shells, along with marine shells, &c. Specimens are very rare." It has also been met with in the Transition Limestone of Gloucestershire, and in the lowest bed of Limestone, near the Hotwells, Bristol.

SUB-TRIBE.—BELEMNITIDÆ.

This is the sixth family of D'Orbigny's classification, in which the animal was furnished with an internal horny or calcareous shell, provided at the posterior part with air-chambers, super-imposed in nearly a straight line, in the form of a cone, and pierced on the ventral portion by a marginal siphon. He has, however, restricted this tribe, so as to exclude some genera, which, we think, come naturally within it, and wherein the animal possessed an internal horny or calcareous shell, with or without a terminal guard, also containtaining air-chambers pierced by a ventral siphuncle.

Genus.—Belemnites.—*Lamarck.*

Generic Character.—Shell straight, conical, consisting of two parts; external portion or sheath forming a thick solid shield, provided with a cavity at the base, to admit the alveole, which is more mathematically conical than the sheath; and is separated into chambers by smooth simple septa, which are perforated by a lateral siphon.

Belemnites abbreviatus. Plate III. figs. 38, 39.

The Belemnites are only known in a fossil state. They have received many vulgar appellations, such as petrified fingers, petrified arrows, thunder stones, spectre candles, and devils' fingers, &c.

This extensive genus is included within the secondary series of rocks. These curious bodies are connected with the other families of chambered shells already described; but differ from them in having their chambers enclosed within a cone-shaped fibrous sheath, resembling in form the point of an arrow, from which their name is derived.

These remarkable bodies have attracted the attention of many authors, from Theophrastus downwards.

Belemnites are composed of three essential parts, which are rarely found together in a perfect condition. They were compound internal shells:—1st, a fibro-calcareous cone-shaped shell, terminating at a larger end in a hollow cone (Plate I. fig. 9); 2d, a conical thin horny sheath or cup, commencing from the base of the hollow cone of the fibro-calcareous sheath, and enlarging rapidly as it extends outwards to a considerable distance (Plate III. fig. 38, *a*); this horny cup formed the anterior chamber of the belemnite, and contained the ink-bag (a representation of a fossil one from Lyme-Regis is given in Plate I. fig. 28); 3d, a thin, conical, internal-chambered shell, called the *alveolus,* situate within the calcareous hollow cone above described (Plate I. fig. 9, *a*, *b*, *b*). This chambered portion of the shell has a near affinity in form, as well as in the principles of its construction, both to the *Nautilus* and *Orthocera.* It is divided by thin transverse plates into a series of narrow air-chambers or *aveolæ,* resembling a pile of watch-glasses, gradually diminishing towards the apex. The transverse plates are outwardly concave and inwardly convex, and are perforated by a continuous siphuncle (fig. 9, *b*, *b*), placed on the inferior or ventral margin.

On Plate I. fig. 29, we have given an imaginary restoration of an animal of this sub-family, exhibiting the probable situation of the ink-bag, and of the internal shell or belemnite. The three component parts of this belemnite are represented as if longitudinally bisected; the place assigned to the ink-bag is nearly the same as in the recent Loligo:—*a*, the apex of the calcareous shell or sheath; *b*, the alveolar portion or chambered shell; *c*, the ink-bag; *d*, *e*, portions of the thin anterior horny sheath, sometimes highly nacreous, exhibiting iridescent or pearly reflections; *f*, the neck of the ink-bag. Upwards of one hundred species of this genus have already been discovered.

Genus.—Belosepia.—*Voltz.*

Generic Character.—Shell internal, oblong, semiconoidal, coarsely granulated or sulcated on the exterior, internally smooth, containing a series of transverse laminæ, perforated near their ventral margins by large elliptical sub-siphoniform openings, and terminating in a solid beak or rostrum, inflected towards the dorsal aspect into an elevated callus, and on the ventral aspect into a semicircular plate, bent outwards over the base of the rostrum, the ventral margins of the laminæ converging towards the anterior extremity of the rostrum, and connected by a thin calcareous plate.

Belosepia Cuvieri. Plate III. fig. 3. Exhibiting its dorsal aspect.

Only four species of this genus have yet been discovered, and these occur in the Eocene deposits of the Paris basin, likewise in those of Belgium, France, and England.

Mr. F. E. Edwards gives the following characters of the *Belosepion,* which term is used to describe the entire internal shell of the *Belosepia,* in the same manner as the term *sepion*

is used by English writers to describe the internal shell of the *sepia*, or what is usually known as cuttle-fish bone.

The *Belosepion*, like the internal shell of the *sepia*, is a compound shell, and consists of—1st, a solid calcareous mucro or rostrum, commonly called the beak, inflected at the posterior extremity towards the dorsal aspect, and at the base expanding on the dorsal aspect into an elevated, compressed, and more or less rugose mass, called by M. Deshayes the *callus*, and on the ventral aspect into a thick semicircular plate bent outwards in a radiated fold, over, but not touching, the upper portion of the rostrum, denticulated on the margin, and continued laterally into the parietes of the sheath; 2d, an inverted semiconical calcareous plate, termed the *sheath*, externally coarsely granulated, internally smooth, but presenting a series of undulating impressions, converging towards the inverted apex, where the sheath terminates in a conical cavity formed in the anterior portion of the rostrum, and strongly inflected towards the ventral aspect, so that the posterior extremity presses against the origin of the radiated fold; 3d, a thin calcareous layer, covering the whole of the inner surface and the terminal cavity of the sheath; and, 4th, a series of thin laminæ or septa imposed one upon another, at first nearly vertically, but assuming gradually a horizontal direction, owing to the convergence, towards the origin, of the radiated fold of their ventral margins, which are nearly straight, and connected by a calcareous plate, forming the ventral surface of the sheath.

Genus.—Beloptera.—*Deshayes.*

Shell internal, composed of two cones placed apex to apex, united and expanding on each side into wing-shaped appendages, obliquely inclined towards the ventral aspect, the anterior cone smooth, longitudinally fibrous, hollowed into a deep conical cavity, containing regular transverse, concave septa, pierced by a ventral siphon.

Beloptera Belemnitoidea. Plate III. fig. 33. Exhibiting its ventral aspect.

Only two species of this genus have yet been discovered; they occur in the Eocene beds of the Paris formation, as well as those of France, Belgium, and England; those of the latter country are peculiar to Highgate and Bracklesham Bay, where the species figured occur as well as the only other species, and are exceedingly rare. In France they occur in the Nummulite bed at Bioritz, in the Lower Pyrenees; the lower beds of the calcaire grossier, at Vivarais, Grypsueil, and Pouchon, and in the puddle beds at Grignon, Parnes, Machi-le-Châtel, Challmont, &c.

The *Belopteræ* present at the anterior extremity a semiconical cavity, slightly depressed on the ventral aspect, which originally contained a thin calcareous layer, covering the entire inner surface. The inner cone formed by this layer contained a series of transverse, regular, and exceedingly thin septa, traces of which, consisting of their sutures, or lines of junction with the inner sheath, are very distinct. These sutures, as they approach the ventral aspect, are slightly bent downwards towards the inverted apex of the cone, and present an acute sinus-like inflection as they rise over a slight linear elevation, which traverses the whole length of the alveolus along the medial line of the ventral inner surface, evidencing the presence and position of the siphuncle. The opening, or anterior extremity of the conical cavity, is slightly elliptical, having the shorter axis in the direction from the ventral to the dorsal aspect. The margin of the outer sheath is thin and sharp, and its ventral paries is much thicker than the dorsal paries, and rises into an elevated mass, depressed on the surface. The outer sheath itself is composed of a series of concentric layers, and exhibits a fibrous texture, like the sheath of the belemnite. The apex is prolonged into a dense calcareous mass, strongly inflected towards the ventral aspect, and enlarged towards the posterior extremity, where it becomes attenuated, and is obliquely truncated. The mass is composed of longitudinal laminæ radiating from the apex of the cone, and so arranged that the central laminæ are in a plane extending from the ventral surface to the back, and the rest in planes gradually diverging more and more towards the back. The outer edges of the laminæ are distinct and slightly elevated, giving a rough sulcated appearance to the surface. The cone, and the calcareous mass into which it is prolonged, expand laterally into two smooth semi-elliptical appendages, inclined obliquely towards the ventral aspect, thin and sharp on the outer edges, and gradually thickening as they approach their bases. These expansions consist of two distinct series of layers deposited on the ventral and dorsal surfaces, and exhibit impressions which, as M. Deshayes remarks, are probably attributable to the presence of a vascular system in the substance of the mantle of the animal. These characters show that *Beloptera* has a much closer analogy to the belemnites than *Belosepia.*

Genus.—Belemnosis.—*F. E. Edwards.*

Shell internal, oblong, semiconical, with the apex inflected towards the ventral aspect, and enlarged into an obtuse umbo, pierced by a pore on the ventral surface, the anterior part hollowed into a deep semiconical cavity extending to the pore, and having the inner surface covered by two calcareous sheaths, one within the other, continued over the ventral surfaces, and enveloping a series of transverse septa, perforated by a ventral siphon.

Belemnosis plicata. Plate III. fig. 34. Exhibiting a side view.

This unique species was found in the London Clay—a member of the Eocene deposits—when constructing the archway at Highway, and is in the cabinet of Mr. Sowerby.

The shell of *Belemnosis* consists of an elongated semiconical sheath, the apex of which expands into a short semicylindrical umbo, pierced in the ventral surface, and inflected towards the ventral aspect. The sheath is convex on the dorsal surface, and is destitute of a ventral paries; the margins at the posterior extremity are narrow, and present outwardly sharp edges, which extend rather more than one-third of the length of the shell; as the margins approach the inferior extremity they expand, and the inner edges gradually approach nearer to each other, until they unite immediately above the umbonal pore. The margins of the pore are elevated, and the pore itself penetrates to, and communicates with, the air-chambers, The septa are transverse and concave; the presence of a siphuncle, and its ventral position, are indicated by angular inflections on the sutural impressions along the medial line of the ventral surface; the septa are continued in, and wholly enveloped by, a thin conical sheath, which also is covered by a second, and somewhat thicker, conical layer, lodged in the outer sheath.

Genus.—Orthocera.—*Lamarck.*

Generic Character.—Shell elongated, straight, or slightly arcuated, with numerous external longitudinal grooves or ribs; chambers separated by transverse septa; these are perforated by a tube, which are either central or marginal.

Orthocera simplex. Plate III. fig. 5. Plate I. fig. 10, is a section of an *Orthocera.*

Sowerby has united this genus with the following, under the name of *Nodosaria.*

Genus.—Nodosaria.—*Lamarck.*

Generic Character.—Shell elongated, erect, or smooth, and slightly arcuated, sub-conic, nodose, consisting of a series of spherical volutions; transverse septa perforated.

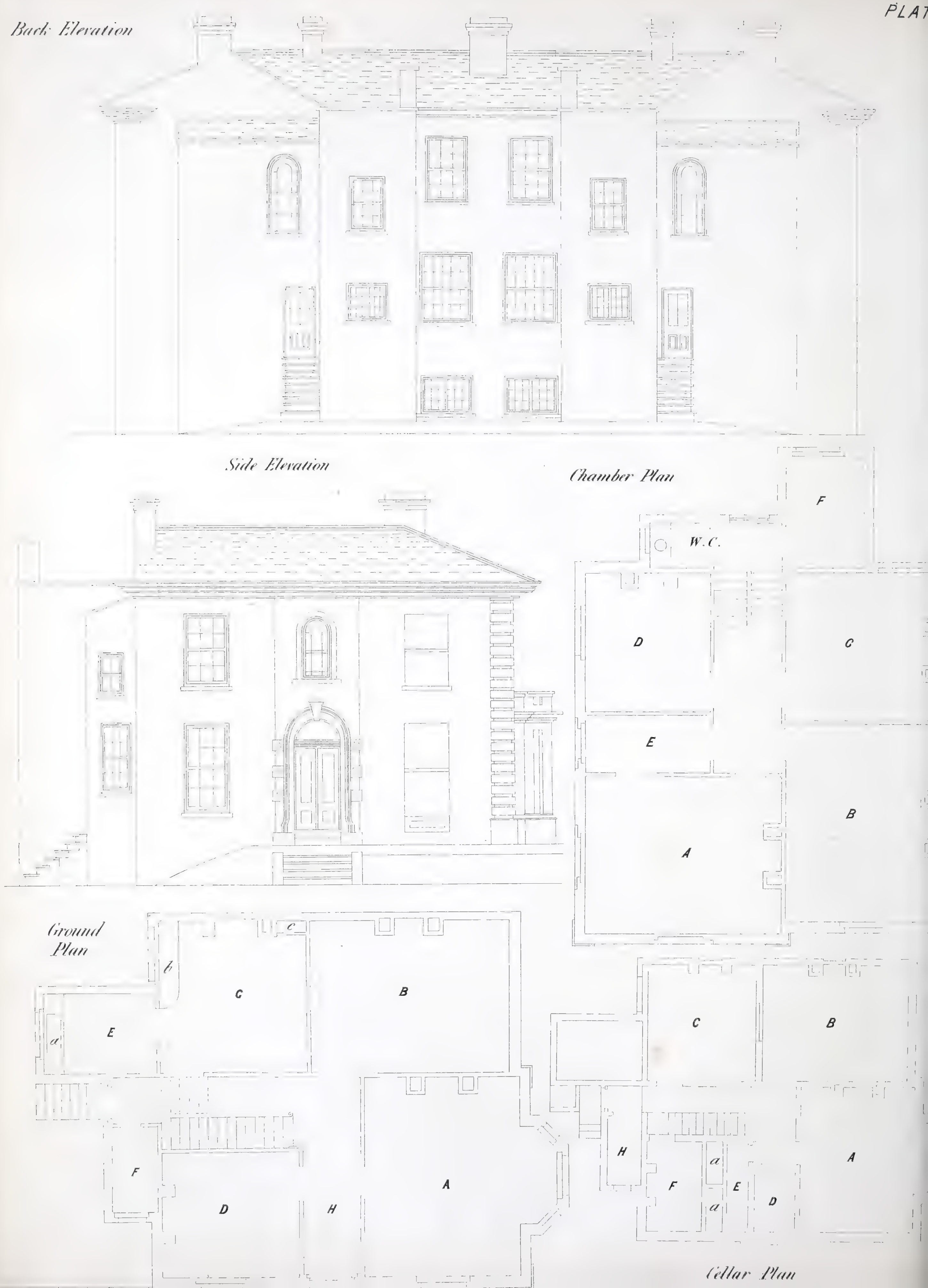
Nodosaria clavatus. Plate III. fig. 23. Exhibiting the internal structure.

Genus.—Phragmoceras.—*Broderip.*

Generic Character.—Shell incurved and compressed, more or less conical; septa entire at their edges, crossed externally by the lines of growth; siphuncle placed near the inner margin; aperture contracted at the middle, its outer extremity produced into a sub-cylindrical beak.

Phragmoceras ventricosum. Plate III. fig. 32.

This genus is distinguished from *Orthocera* by the shells being curved, and by the siphuncle being nearly marginal. The species are known only in a fossil state, and are characteristic of the Silurian system of rocks.


Back Elevation
Side Elevation
Chamber Plan
F
W. C.
D
C
E
B
A
Ground Plan
c
b
C
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E
a
F
A
D
H
C
B
H
a
F
E
D
a
A
Cellar Plan

Genus.—Amplexus.—*Sowerby.*

Generic Character.—Shell cylindrical, multilocular, with numerous transverse septa, which embrace each other with their reflected margins.

Amplexus Coralloides. Plate III. figs. 29, 30.

This curious fossil strongly resembles a zoophite. It is found in the Limestone, called Black Rock, at Limerick, Ireland.

BUILDING ARTS.

CHAPTER II.

Specification Continued.

MASON.

The groins, base-course, bow-windows, balcony bottoms, panels under ground, floor windows, window sills, door dressing, and step coping, to be of Bath stone, all well and finely wrought in the very best manner, to the form and dimensions shown in the drawings, or specified.

The base course to be twelve by six inches, weathered, and to project one-and-a-half inch.

The groins to be two feet three inches and a half wide, three inches projection from face of brickwork, and six inches thick, jointed alternately, and cramped with cement cramps, as directed. They are each to have a rustic, three inches by one, wrought on the bottom, and to be stopped at the face of brickwork, the lower edge of rustics to be weathered one-eighth of an inch.

The two balcony bottoms to be six inches thick, five feet eleven inches long, and two feet five inches wide, and to be well wedged into the walls. The front to be cut elliptical, and moulded, as shown in the drawing.

The panels under four windows to be one foot eight inches deep, nine inches thick, and to have a sunk panel and moulding four inches girt.

The window sills to the front and ends to be eleven by six inches, wrought, weathered, and throated.

The door to have an architrave and blocks, vermiculated, as shown in the drawings.

The key-stones to have heads carved thereon, and moulded caps.

The bases under the groins, and the caps above the same, are to be jointed in the centre, and to be two feet nine inches deep.

The caps to be nine inches thick. The bow-windows to have bases two feet eleven inches total depth, and moulding wrought in the same.

The mullions to be each in one stone, eight feet long. The blocking above cornice to have one front stone six inches thick, with carved panel, as shown in drawings.

The chimneys to caps or strings moulded, and with blocks, as shown, twelve inches by eight inches, with blocking above, six inches by four inches.

The steps to have toad back coping and piers, as shown by drawings.

Provide and run with lead twenty cramps to chimney caps; also twenty-eight cramps, nine inches by one-and-three-quarters inch, and run with cement. The whole of the above-mentioned cramps to be used in such parts of the building as the architect shall direct; and to be let into stone, and bound down at ends three-fourths of an inch.

Provide and let into stone, and run with cement, thirty-two slate dowels, three inches by two inches, to bow-windows.

Provide for the back windows, twelve inches by six inches, wrought, weathered, and throated window sills, of (*here the quality and name of stone should be given*). The cistern walls to have twelve inches by three inches, tooled edges, coping cramped. The servants' bed-room chimney to have a six-inch tooled and weathered cap, two feet seven inches by two feet two inches, and perforated for flue.

The entrance door to have a seven-inch polished landing, well bedded on the walls, and the front edge forming step. The back doors to have eight-inch landings, four feet three inches by two feet, tooled, and two steps each under the same, four feet full length, one foot three inches wide, and sunk out square at the nosing; also, a bottom step, four feet six inches long, one foot three inches wide, with square nosing, sunk and rounded ends. The intermediate steps and risers to be tooled three inches thick, and laid upon brick spandril walls, and set to form square nosings, as shown.

The area walls round the cellar doors to be twelve by three inches, tooled on edges. The bottom to be laid with three inches flagging.

Prepare and fix to the arch of back entrance steps ten wrought-iron ballisters, one inch by three quarters of an inch; two newels and wrought-iron railing complete. The above are to be well let into the stonework, and run with lead. Provide and fix a scraper at the foot of each flight of steps, of the value of . . .

The front door inner step to be three inches thick, sixteen inches wide, and riser both polished and moulded nosing wrought on the step.

The whole of the cellar doors to have a complete set of cod and sneck stones. The coal-place shoot doors to have sills, six inches by three inches, tooled on edge.

The boilers to have three inch tooled boiler tops, and edges sounded.

The kitchen, pantries, sculleries, and back lobbies, to be paved with two-and-a-half inch (*here describe the quality and name of stone to be employed*).

The lobby doors to have three-inch tooled steps and risers.

To provide and set a six-inch tooled and sunk slopstone to each house, eight feet long, two feet wide, and twelve-inch polished skirting, set with cement, and cramped.

The stones to be properly holed and complete. Provide and set two-and-a-half inch polished hearths and back hearths.

The mason to provide and fix two cellar chimney-pieces, of the value of (*here name the price*) net before setting; also two kitchen chimney-pieces of the value of (*here name the price*) net before setting.

The remainder of the chimney-pieces to be provided and set by the proprietor.

The whole of the stone-carving to be done by (*here state name and address of person*), and the contractor to pay him the sum of (*here state the amount*) for the same.

Provide and set, where directed, twenty stone corbels, nine inches by six inches by three inches, for bedding end of timber at flues, &c., &c.

The front entrance steps to the terrace to be seven feet long, one foot four inches wide, polished, and set in five inches by three inches polished risers to form square nosings.

The larders to have each a stone (meat) slab, nine feet by three feet, three inches thick, and polished on top and edges.

The cast-iron balconies to be let into stonework, and run with lead.

The entrance porch to be skirted with polished skirting, seven inches deep, and cramped.

Provide four nine-inch by three-inch area curb-flags, tooled in edge and set in sills, sixteen inches by three. Also, two area curbs, twenty-four inches by three inches, on sills twenty-four inches by three inches.

The roof and floor of privies to be covered with two-and-a-half inch (*here state name and quality of stone*) flags; those to the roof to lap four inches, and be laid with fall sufficient to throw off the water into dungheap. Provide and fix a polished urine flag to each privy. The privy windows to have three-inch self-faced flag sills, tooled on edges.

The front wall and one foot extra of the return at each end to be faced with hammer-dressed stones of the best quality, in courses about four and a half inches deep and nine inches thick on bed. The facing to be three feet nine inches deep from under side of coping, and the edges to be tooled. The wall to batter two-and-a-half inches. The corners next angles to have piers about two inches projection. The coping to be of summit stone, sixteen inches by six, to be tooled on edges only.

The four gate-posts to be of (*here state name and quality of stone*), finely wrought and moulded, as shown in the drawing (*see Plate IV.*) Each joint to have two slate dowels, three

inches by two inches, and to be run with cement. The lower stone of each gate-post to be three feet nine inches long. The vermiculated work to be done in the most superior manner.

The whole of the stonework above-mentioned to be wrought, polished, and moulded according to the present contract drawings, further additional instructions being given during the course of the work.

The joints of all stonework to be arranged under the architect's directions. The mason to find all cramps and dowels required throughout the building, and lead and cement for running the same.

The cramps to be well steeped in linseed oil. Provide and fix all temporary covering required for the protection and preservation of the stonework.

The mason to cut all holes, mortices, and backings for door-posts and casings; all grooves for lead flushings or other purposes, recesses, notches, &c., required in the stonework—to carefully fill all joints exposed to the weather with oil mastic or other cement, so as to be perfectly weather-proof—to clean the stonework after the completion of the building, agreeable to the directions of the architect—to leave blocks in the stonework just sufficient for the carving, and complete the remainder of the work all round the same—to provide all carriages, materials, workmanship, all tackling, tools, moulds, templates, and any other matter or thing, of whatsoever description, required for the due and proper execution of the mason's work.

CARPENTER AND JOINER.

The whole of the bearing timber to be of the very best Quebec pine, and the remainder of (*here state the name and quality*) of the very best quality, except where otherwise specified.

All the deals are to be at once brought upon the ground. All the joiner's work to be framed as soon as possible. Any unsound or unseasoned timber will be strictly rejected.

Provide all centres and turning pieces for the bricklayer; also, all staff beads, grounds, &c., incidental to carpenter's work.

Lintels, seven inches by three inches, to be fixed to all the external openings, and to bed in the walls nine inches at each end.

Lintels, three inches thick, covering the whole width of the walls, to be bedded nine inches at each end over all the internal openings requiring the same.

Provide and fix, where directed, four hundred and fourteen nogs, nine by four-and-a-half by three inches; thirty-six nogs, nine by nine by three inches, for large doors; and six hundred skirting nogs, four-and-a-half by one-and-a-half by nine inches.

Each bow-window to have two lintels or brest-summers, twelve by six inches, and to lie in the walls one foot at each end.

The whole of the floor joists to be cocked down upon wall plates, four by two inches.

One row of bond timber, four by three inches, to be laid on the whole of the walls of the two upper floors, and two rows to each cistern.

The whole of the above to be in long lengths, halved and spiked, and the angles to be fixed at such heights as shall be described, and go round all the brick breadth walls, except the fire-places.

The wall over staircase to be supported with a trimmer, ten by five inches, and to lie one foot in the walls at each end.

The joists to the passages, pantries, sculleries, water-closets, cistern, and servants' bed-room, and dressing-room and drawing-room, to be seven by two and a half inches, and trimmers seven by three inches.

All the rest of the floors, &c., to have joists nine by two and quarter inches, and trimmers nine by three inches.

All the joists to be thirteen inches apart, and to have one row of bridging, eight by one-and-a-half inches down the centre of each floor.

The whole of the joists are to be laid, and the hearths trimmed and boxed with trimmers, five by three inches, as shall be directed.

The whole of the floors to be laid with seven by one inch spruce floor boarding, laid straight joint, nailed down, punched, puttied, and traversed off when the plastering is completed.

All the hearths to have a two-and-a-half inch mitred margin round.

All the flag floors to have one inch rough flagging boards.

The ceiling joists to be four by one-and-a-half inches, sixteen inches from centre to centre, well hung to rafters.

The entrance lobby to have circular curved ribs in two thicknesses, four by two inches for plastering, and the porch to have ribs in one thickness, four by two inches circular.

The roof to have wall-plates, six by three inches; pans, eleven by three inches; pole plates, twelve by three inches; ridge pole, seven by two inches; hip rafters, twelve by two inches; valley rafters, twelve by three inches; smaller valley rafters, ten by three inches; angle and dragon ties, six by four inches; common rafters, thirteen inches apart, three-and-a-half by two inches; valley boards eight by one inch. Inch rough cistern boards to sides and bottom; one-and-a-half inch curved ribs to ceiling over staircase. Eaves pole, two-and-a-half by one-and-a-half inch; centre gutter boards, twelve by one inch; and bearers, two by two inches. The front gutters to have boards, nine by one inch, and two by two inch bearers; back gutters to have ten by one inch moulded fascia boards, and seven by one inch gutters and bearers. Provide and fix two cross gutters where shown, bottom eight by one-half inches, sides six by one inch. The gutters are all to be laid to as much fall as can be obtained, and to have eight cesspools, eighteen inches long by six inches deep, and the whole width of gutter prepared for pipes. Form gutters at the back of chimneys. Prepare and fix a moulded cornice to the front ends, and four feet of the returns at the back; three-eight inch girt, with moulded blocks, &c., complete. The whole to be made of the size, profile, and strength shown in the detail drawings, Plate III. The cornice gutters to be constructed with inch rough boards and brackets, two-and-a-half by one-and-a-half inches, as shown.

The partitions to have posts four by four inches; quartering, four by two inches; heads and braces, four by three inches.

Cover the flat over bow-windows with five by two inch joists, and inch lead boarding laid to the fall to pipe heads. The front windows to have two inch red deal moulded sashes, made for thick plate glass, and frames with red deal sunk sills, one and a quarter pulley stills; and to be hung with the best hemp white lines, patent axle pulleys, large iron weights, and brass sash-fasteners complete.

The dressing-room windows to have circular-headed and moulded sashes and frames, and prepared for common glass, with marginal squares, and lines, weights, &c., as described for the above. The staircases to have fixed sash sheets, two inches thick, moulded marginal squares and circular heads. The scullery and larder to have two inch moulded Yorkshire lights, and proper frames, with sash-fasteners complete. All the rest of the windows, not hitherto specified, to be moulded two inches thick, with deal-cased frames, and red deal, sunk, weathered, and throated sills, brass sash-fasteners, best hemp cords, iron weights, and patent axle pulleys. Prepare and fix a borrowed light, five by two feet.

The entrance doors to have fixed moulded fanlights, made for one sheet of plate glass, quarter-inch thick.

Prepare for the back entrances on ground floor, two-inch sash moulded doors, six feet eight inches by three feet, and hung to five-inch by three-inch rebated and beaded frames, with two by three-and-a-half inches butt. Each sash to be prepared for the bead butt shutters, and to be in four squares of glass. Provide and fix studs, screws, and chains for the shutters, also a ten-inch carpenter's lock and chain to each door, and two six-inch barrel bolts complete. Fix single moulds round the inside. The outside entrances underneath the above to have inch-ploughed, tongued, and lodged doors, hung to five by three-inch rebated frames, with sixteen inch Scotch T hinges. The doors to have thumb-latches, ten-inch stock locks, and six-inch flat iron bolts. Fix single moulds round the inside.

Each front entrance to have a two-and-a-quarter inch bolection moulded sash folding-door, eight feet three inches by four feet six inches, the upper part to be made for thick plate glass.

The doors to be hung to six by four inch wrought, rebated, and beaded posts, with two four-inch butt hinges each. Provide and fix to each door an eight by three-quarter mortice lock and chain, and one eighteen-inch and one twelve-inch brass flush bolts to each pair of folding doors. The upper part to be prepared for one-and-a-half inch moulded shutters, four feet by two feet nine inches, and to have shutter-lifts, thumb-screws, chains, studs, &c., complete. Prepare and fix a transom on each side over the door, three by one-and-a-half inch moulded, also five-and-a-half inch single architrave on the inside, and wide single mould on the outside, with blocks at the bottom.

Prepare and hang with sixteen-inch Scotch T hinges to five by three inches rebated frame, inch ploughed, tongued, and bevelled and ledged doors, six feet by two feet eight inches in each cellar. Also, four doors in each cellar, six feet by three feet, hung as above; the whole to have Norfolk latches, and six of the above to have eight-inch stock locks. The passage side of these doors to have single moulds in all cases.

Provide and hang with two twelve-inch Scotch T hinges, to four by three inch rebated frames, two coal-place doors, three feet by two feet three inches, and fix two six-inch flat bolts and staples to each door.

The dining, drawing, and sitting-rooms in each house to have two-inch double-moulded doors, six feet ten inches by three feet, hung to one-and-a-half-inch wrought rebated door-casings, with two three-and-a-half-inch butts. Each door to have a seven by five-eighths mortice lock and brass furniture. Fix seven-inch double-faced architraves on both sides, and coved blocks.

The kitchens to have each a one-and-three-quarter-inch, moulded both sides, door, six feet eight inches by three feet, hung to one-and-a-half-inch rebated casings; five-and-a-half-inch single architrave on passage side, with single mould on kitchen side, and to have a seven-inch carpenter's lock and brass furniture.

The pantry, scullery, servants' bed-room, and water-closet in each house, to have a one-and-a-half-inch moulded and square doors, six feet six inches by two feet six inches, hung to one-and-a-half-inch rebated casings, with three-and-a-half-inch butt. To have single moulds on both sides. The water-closets to have carpenter's latch and brass bolts, and the other doors to have seven-inch carpenter's locks and brass furniture.

The remainder of the doors to chamber-floor in each house to be one-and-three-quarter-inch thick, moulded both sides, six feet eight inches by two feet eight inches, hung to one-and-a-half-inch rebated casings, with three half-inch butts. To have five-and-a-half-inch single architraves on both sides, and seven-inch carpenter's locks and brass furniture.

The four windows to the breakfast and dining-rooms to have one-and-a-half-inch moulded and bead butt folding window shutters, hung with three pair of three-inch butt hinges each, and three pair two-and-a-half-inch back lap hinges—to have top-rail four inches deep, one-and-a-half-inch beaded capping, one-and-a-quarter-inch moulded backs, elbows, soffits, three-eighths window beaded capping, nine by one-and-a-half-inch framed grounds, six-inch single architraves and coved blocks, nine by one-and-a-half-inch beaded backing, inch bead butt back lining. Shutter bars two feet five inches long. Shutter latches and brass furniture complete, as may be more particularly described hereafter.

Prepare and hang to the bow-windows one-and-a-half-inch folding shutters, as above, hung with pivots, top and bottom. The back laps to be hung up with three two-and-a-half-inch back laps, each to have rails, two inch by three-eighth-inch beaded capping, inch-beaded back lining, nine-inch by one-and-a-half-inch beaded grounds, six-inch single architraves fixed on ground, five by one-and-a-half-inch back lining, coved blocks, three-quarter-inch lining at back of mullions, and single mould planted on the same for panels—one-and-a-fourth moulded lining to mullions. Shutter latches, and brass furniture shutter bars, two feet long, and three six-inch brass flush bolts to each, complete.

The stair case windows to have two by one-inch lining, six-inch single architraves, four by one-and-one-fourth moulded window bottom, with small blocks and bells underneath, as shown in the section. The bed-room windows to have two by one-inch linings, and six-inch single architraves, one-and-one-fourth moulded and beaded backs. All the rest of the windows throughout to have one-inch linings single moulds round, and window bottom three by one-and-one-fourth inch moulded, complete.

Prepare and fix twelve by one-inch beaded casings to pipes where required to the water-closets. Prepare and fix one-and-one-quarter-inch straight pitch pine steps, riser and quarter spaces, three feet one inch long; one-and-a-half-inch moulded boards and string boards, moulded return nosing and cut brackets; iron ornamental balusters, two to each step; two by two-and-three-quarter-inch best Spanish mahogany hand-rail spring trees, five by three inch Spanish mahogany polished octagonal newels, four-and-a-half by four-and-a-half, with carved caps. Prepare and fix to the closet and servants' bed-room, inch steps and risers as shown on plan, with moulded nosings. Prepare and fix to the cellars twelve one-and-a-half inch steps, each three feet long, let into one-and-a-half-inch notch boards, with three by two birch hand-rails, iron newel, and iron balusters to each staircase. The whole of the above treads and risers to be made as shown on plan. Line the staircase landings with rich-beaded lining and moulded nosings.

The staircase on ground floor to have a one-and-a-half-inch moulded and square spandrel, with cellar door six feet three inches by two feet eight inches hung thereto, with three-and-a-half butts, and to have seven-inch carpenter's locks. The whole to be furnished with single moulds round the door, and elsewhere directed. The lobby to have one-and-a-half inch moulded pilasters, with moulded caps seven inches deep, and moulded bases two inches deep, as shown by enlarged drawings.

The dining and drawing-rooms each to have a twelve-inch double base. The breakfast-rooms and lobbies to have a ten-inch moulded skirting. The servants' bed-room and water-closets to have a six-inch iron skirting. The bed-rooms and lobbies to have eight by one-inch moulded skirting. The kitchens, sculleries, and back bed-rooms to have a seven-inch torus skirting.

Provide and fix angle staff-beads to all external angles. Prepare and fix to the six-inch walls, in cellars, four-and-a-half by three-inch wrought coping, rounded. Prepare and fix in each house 50 feet of three by one inch beaded-work rail and brass work; sixty feet of fifteen by one-and-a-quarter-inch wrought shelves and brackets to larder; and one hundred feet of shelves and brackets, twelve by one inch. The brackets to be neatly inwrought and chamfered, and the shelves to have rounded edges.

Prepare and fix to each kitchen a cupboard and drawers, the whole height of room, three feet wide, one-and-a-quarter inch moulded and framed front, eighteen by one inch shelves, one and a quarter drawer fronts, three-quarter inch sides, bottoms and backs. Three drawers deep, with two black knobs each; the cupboard to have good brass turns, hooks and eyes; also, ten feet of three by three-quarter pin rail and brass hooks, single moulds all round. Square skirting, drawers, runners, &c., complete.

Prepare and fix two hatch-doors in roof, and two man-holes, two feet square, with lining, molds, trimming, iron-work, &c., complete. Prepare and fix to the outside front wall, where shown in elevation, ornamental lattice-work, for creeping plants, as directed, at the value of when fixed. Prepare and fix for the dung-heap and ash-pit, nine by three inch wrought Baltic sills. Privies to have one inch seat and one-and-a-quarter-inch clump fall, three-quarter-inch batten door, hung with twelve inch T hinges to four by one-and-a-half inch rebated casings and single molds inside, Norfolk latch and four inch bolts. The falls to be hung with two inch butts; four-and-three-quarter-inch beaded skirting; one quarter and-a-half-inch fixed sash eighteen square, casings and single molds complete. Also, ash-pit door, two feet square, and frame with iron-work complete. Provide and well screw to the wash-house windows twenty wrought-iron bars, three-quarter by three-quarter inch. Provide two cast-iron balconies of the value of . . .

HISTORY.

CHAPTER XXIII.

THE MORAL AND INTELLECTUAL CHARACTER OF THE NATIONAL GOVERNMENTS.

In last chapter we disposed our observations on the period now under consideration,—between 1519 and 1788—in the following order of arrangement:—First, the progress of the internal organization of the states of Europe; second, the history of the church; third, the relations in which the great states of Europe came to stand to each other during this period in consequence of the changes in their political structure and religious faith. The first two heads we have already disposed of: it remains to discuss the third briefly before proceeding to any attempt to estimate the moral and intellectual character of the age of territorial governments, and the balance of power.

III. For some time previous to the overthrow of the western empire, the whole of Europe, with the exception of central Germany and the provinces beyond the Baltic, stood under one government. Subsequent to the dissolution of the western empire, during the continuance of the first hastily constructed Teutonic kingdoms and the feudal governments, the territorial relations of Europe were vague and shifting. The remembrance of the time when Europe had one supreme head, to whom all doubtful and important disputes could be referred, still survived dimly in men's minds: the successors of Charles Martel aspired to fill the place. The popes of Rome, as soon as they felt the full strength of the organization, the central power of which was vested in their hands, aspired to supply his place. Neither party felt himself strong enough, however, to erect a new dynasty of such extent. They played into each other's hands. The sovereign of the Franks, threw his political influence into the scale of the Romish Pontiff; and the Romish Pontiff gave the sanction of his spiritual authority to the Frankish monarch. In Spain and France the growing sense of nationality rendered the monarchs independent. In Britain the imperial authority had never been recognised. In the Germanic states alone was the emperor's title still recognised: and even there the extent of territory was so great, that the great vassals soon became even more than in the other countries of Europe, virtual sovereigns.

With the first revolt against the spiritual supremacy of Rome we may date the acknowledged substitution of national for feudal governments. The substructure had been for some time laid, and the walls were noiselessly rising, but now they became visible. It was some time before the arrangements of the new system were completed; indeed, till this day, they cannot be said to be completed. But at the point of time to which I refer they were strong enough, and men became sufficiently familiarized to them to allow us to adopt it as the date of their erection.

The great natural nations of Europe, as marked out by language, customs, and sense of brotherhood, were, as we have already pointed out, five in number:—The Italians in the long narrow strip of land stretching out from the Alps into the waters of the Mediterranean; the Spaniards in the territory south of the Pyrenees, washed by the waters of the Atlantic and the Mediterranean; the French in that part of Europe lying between the Pyrenees and the Rhine; the British inhabiting our own islands; and the Germans surrounded for many miles by Italy, France, and the Baltic, with an indeterminate boundary on the east. The tendency was, under the influence of the growth of the national spirit in each of these sections, for the inhabitants of each to unite into one state, but circumstances prevented the complete consummation of this tendency. The inhabitants of the Iberian Peninsula continued split into two nations, the Spaniards and Portuguese. The inhabitants of the British isles continued for a time to exist as two separate independent states, the Scottish and English, latterly united under one crown, and finally incorporated. Italy may be viewed as containing no less than seven independent states:—the republics of Venice and Genoa, the Dukedoms of Milan, Ferrara, and Florence; the states of the church; and the kingdoms of Naples and Sicily. The confederated Swiss cantons occupying the western portion of the Alps, and bordering upon Italy, France, and Germany, had, so early as 1308, asserted the position of an independent member of the empire; towards the close of the fifteenth century, circumstances drove them to declare themselves in their united capacity, a sovereign state altogether independent of the empire. Under Philip, the heir of Charles V, religious disputes occasioned the secession of the seven united provinces from the north-western extremity of the empire. These provinces, now the kingdom of Holland, along with that portion of the Netherlands now erected into the kingdom of Belgium, and several provinces now incorporated into France and the Germanic confederation, were the inheritance of the grandson of the heiress of Charles the Bold. At his demission of the throne they fell with Spain to the throne of Philip. They were not like Spain, however, an independent state; but a fief of the empire. The eagerness of that bigotted monarch to repress the progress of the reformed religion, led him to infringe the civil as well as the religious liberties of the sturdy Hollanders: and the struggle thus occasioned ended not only in the casting out of the Spanish branch of the House of Austria, by the seven most northerly provinces of the Netherlands, but in their secession from the empire. Although the great feudatories of the empire did not declare themselves independent, yet the weakness of a sovereign elective (at least in theory), was little capable of restraining them; and, in addition to this, several of them came in course of time to obtain the kingly title in virtue of territories situated beyond the limits of the empire; and this title encouraged them still more to rule within their imperial fiefs as independent sovereigns.

It is in human nature to find frequent wars occurring between neighbouring independent states. Kings fight for territory; popular governments, because of grudges between the citizens. But there were circumstances which gave a peculiar character to the wars between the states of Europe, and produced a peculiar result.

In the first place, there was in every state a national spirit—certain classes of the citizens, if not the whole community, felt that they had rights, and the will and power to assert them. This was the case not only in the republics of Switzerland, Holland, Genoa, and Venice, but also more or less in the monarchical states. The weakness of the emperor kept the feudatories in more than full possession of their feudal rights and immunities. Under the influence of these circumstances, the sense of national independence—of hatred of foreign domination, grew stronger and more inveterate. Men became daily more accustomed to think and say, all the land within such and such boundaries is the inheritance of us, the people speaking one language, holding one faith, enjoying common privileges, owning one sovereign or government.

In the second place, the lust after the phantom of universal domination had vanished from the minds of rulers. Original relationship and intermarriages had made the greater part of the sovereigns and high nobility of Europe near akin. Although the feudal system had, in a great measure, ceased to give form to the affairs of state, it still continued to give form to that portion of distributive law which regulated property in land—and more especially to the law of inheritance. Monarchs at times became heirs of more than one throne, and frequently they became heirs of property lying within the limits of foreign states. Incidents of this kind were greedily made available for the purpose of extending their dominions; and it sometimes happened that a sovereign, whose power was much increased by such events, conceived anew the old project of extending his sovereignty over the whole of Europe. Charles V, hereditary sovereign of the Netherlands, the wealthiest and most populous portion of northern Europe, and, in addition, the nominal head of Germany, was naturally fired with this ambition. At a later date, Louis XIV seems to have conceived the same bold project. The ambition first of the house of Austria, and then of the house of Bourbon, became objects of serious alarm to the neighbouring, and more especially to the wealthier, states; and out of this emotion arose defensive leagues—associations of states for the mutual assurance of national independence.

A third circumstance which contributed to lend a peculiar character to the wars and other transactions of European states during this period, was generally dignified with the name of religious zeal, but was too often, even when it was sincere, nothing better than sectarian partizanship. While the growth of the national spirit tended to isolate the people of Europe into unsympathising denizens of independent states, the contravening between the Romish and the reformed churches, more than any thing else, tended to keep alive a sense of common European citizenship. Their relation to the Roman see was a kind of union between Catholics through the whole of Europe. The consciousness of this bond was kept alive by the incessant activity of the Jesuits, and their affiliated societies. On the other hand, this union among the Roman Catholics, which fancy painted even stronger and more dangerous than it was, tended to counteract the sectarian jealousies and theological rancour of the Protestants, and to unite them for self-defence. Thus, while nationality made every Frenchman ready to ally himself with every other Frenchman against any foreigner, the Huguenot and the Lutheran, although the one

was a Frenchman, the other a German, were ready to ally themselves against the Roman Catholic, be he French or German. This source of cabals and strife became mixed up with those dissensions arising out of the thirst of territorial aggrandisement, and rendered them more complicated. The struggle between the seven united provinces and the king of Spain, was in fact a struggle in which the Protestants both of Germany and France had an interest; and as a consequence assistance was afforded to the Hollanders from both France and Spain. Again, in the person of Elizabeth, the sovereign's right of succession to the English throne came to depend upon the permanent establishment of the Protestant tenets. Here was an inducement for the English government to support the Protestants in Holland against Philip, and the Huguenots in France against the league. This complication of political and religious motives produced yet more extraordinary alliances. During the latter years of the reign of Louis XIII, Richelieu, a Cardinal of the Romish church, dreading the preponderance of the house of Austria, allied himself with the Protestants of Germany, whom the emperor (in his capacity of good Catholic), was there endeavouring to crush, and in his zeal to crush a rival political power saved from destruction the enemies of the church in which he held so high an office.

During the earlier portion of this period, the international relations of Europe were a chaos, men were influenced by national and religious prejudice—sometimes counteracting each other, sometimes operating in the same direction. The development of European intellect, and the growth of European morality, rapid and brilliant though they had been, had as yet done more to vivify and invigorate than to enlighten men. A sense, rather than a knowledge of what was just, began to pervade society. Increased skill in forensic debate, and in the art of war, by increasing the conscious power, and therewith the pride of men, co-operated with more refined and more generous sentiments—as is not unfrequently the case with young genius—at times only to drive them further astray than dull or sluggish souls could go. Europe had arrived at that stage of civilization, in which the dazzling and startling is far more attractive than the substantially good. It is while men's minds are in such a state that sinister ambition finds it most easy under spurious pretences to convert them into its tools. The selfish ambition of princes, appealing alternately to national spirit, and to religious zeal, kindled incessant wars, and these carried on by people of equal hardihood, equally advanced in civilization, and more powerful than of yore, in virtue of augmented intelligence and wealth, were distinguished from all former wars by the amount of devastation they occasioned, and the paltry inadequacy of their results.

All this while a remedy was growing up, exhausted Europe groaned for peace, and its better spirits were devising means for introducing and perpetuating it. The celebrated treatise of Grotius, "*de jure belli et pacis,*" was mainly efficacious in laying the foundations of a better system. The object of this great and good man was to establish those cases in which one government or nation was justifiable in commencing hostilities against another; the mode in which war might justifiably be carried on; the relations of belligerents, allies and neutrals; and the mode of conducting treaties by which an end was to be put to wars. The ground taken by Grotius was that of regarding states in their relations to each other as corporate bodies, each of which was sole and exclusive proprietor of the soil subjected to its government. These corporate bodies were, as it were, the citizens of a great republic: each had his rights, and, when attacked by another, the whole were entitled to sit in judgment. If the party attacked was sufficiently powerful to repel the assault, he might do so: if not, he might call in the assistance of neighbours, who being liable to similar injustice, had the same interest to assist in repelling it. All the belligerents were bound to abstain from injuring neutrals in their attempts to injure each other. Neutrals, on the other hand, were bound not to lend assistance to either belligerent, under penalty of losing their neutral character, and becoming liable to attack. Certain nefarious methods of commencing and conducting warfare were denounced as immoral. The age was ripe for such a work. Men could appreciate its moral and imaginative beauty. The consolidation of the laws and tribunals within every state of Europe, by the sanction of time, had trained the mass of society to habits of thought and feeling, had prepared them for the extension of legal precepts to international affairs. The doctrines of Grotius were soon taught in every university of Europe; and the greatest statesman of his age sought instruction in his book. It was the inseparable companion of Gustavus Adolphus: the most conspicuous article of furniture found in his simple tent after his death. True, the European republic was like an Indian tribe—an assemblage of citizens without any acknowledged ruler. It was by compact among each other, not by the sanction of authority, and consequently by degrees that the doctrines of international law came to be adopted. They made their way, however, for men felt their justice and utility, under the parallel influences of teachers in the universities, and diplomatists in the cabinets, until out of the treaties of the one, and the machinations of the other, has grown up the system which we find delineated with sufficient accuracy in the writings of Vatel and Martius. It may not be so well conformed to as is desirable, the unavoidable result of each state being judge in its own case but its recognition even in theory has been productive of incalculable benefit to humanity.

We shall now turn our attention to the intellectual and moral character of the national governments of Europe during the period which we have been passing in review. The phenomenon which most imperatively claims our attention in the prosecution of this review is the progress made by art, science, and literature during the period: for it was mainly through them that the community of European character was preserved. The tendency of the development of national character under the auspices of local position and fully developed languages, corroborated by the establishment of national governments, went to isolate the citizens of the different states from each other and render them dissimilar. This tendency was imperfectly counteracted by commercial intercourse, and sectarian leagues and alliances. Art, science, and literature, in combination with a more general diffusion of instruction, were the great preservatives of a common European character amid all national diversities. From the common source of the classical authors, derived through tradition, or through the school of Alexandria, men had inherited a theory of art and literature. In every country in Europe, the conventional criticism of these kindred products of imagination was learned in the same school. The influence of the Latin language, methodised by the aid of Greek grammarians, in forming all the languages of modern Europe, had cast staple forms of expression in one mould, and the reaction of these upon the forms of thought it is scarcely possible to calculate. The scholars and artists of Europe spoke and thought in one common language, although the dialects might differ. There is a community of thought, and even of diction, among the great poets of Italy, England, and Spain. Whoever can enter fully into the spirit of one, can easily read himself into that of the other. In what is more technically called art—painting, sculpture and music, there is a less wide and varied range than in the world of ideas, and as in these, all started from the same point, we are less surprised to find a greater sameness of technical character.

The first burst of the young imagination of Europe was almost terrific. It was as if the great fountains of the deep of the world of spirits had been broken up, and all the floods were coming surging and nearing in upon us. The Spaniard was more fervid and stately, yet shrewd and discerning withal. In some of Calderen's pieces, and more especially in his "Life is no Dream," there is a mysterious disembodied character, as if the spirit freed from matter were floating amid gorgeous and shifting shows of unsubstantial sounds, and forms, and colours. In Cervantes we have the very soul of impassioned chivalry. And in both, when they give a loose to the vein of merriment, we have the redundant and over-powering tide of humour of an intense mind which rarely yields to the emotion, and gives way the more entirely to the pressure of the accumulated torrent. In Italy we have an equally fervid temperament, with less power of self-restraint, never allowing the same force and pressure from never meeting the same check. In glowing warmth, Boccacio, Ariosto, and Tasso are alike, although the one runs riot as often in the ludicrous as in the impassioned, the other flutters gaily from flower to flower like the butterfly, and the song of the latter is one prolonged melodious sigh. In Shakspeare and in Spencer we find the melody, the gorgeous colouring, the warmth of passion, the laughter of light-hearted ease, as redundant as in the others, with perhaps a greater universality, a more unbounded sympathy. In Germany this spring-tide of young emotion was expended in theological controversy: it is in the personal character of the German contemporaries of the mighty names I have mentioned, not in their writings, that we recognise the congeniality of their spirits. In the wild, reckless outpourings of Rabelais alone is a kindred power and character to be found in France.

While the spirits and imagination of young Europe were thus running riot, a change was coming over the spirit of its philosophy. Before this age, the pure intellect had achieved perhaps as much as it can ever achieve for itself. Now men everywhere began to turn their attention to observation. Tycho Brahæ, the father of patient astronomical observation, was still busied in his labours when Galileo availed himself of the invention of the telescope to bring

the bright objects of their common watch nearer to the eye; and Kepler of his wonderful powers of combination and calculation to infer the reality of celestial existences from the phenomena observed. About the same time the inventor of the barometer turned attention to the mechanical action of the air; and, in the laboratories, the distillers of essences and the dreamy alchymists were observing and recording facts, from which in due time the Blacks, Lavoisiers, and Franklins, evolved the science of chemistry. About the commencement of the fifteenth century the Algebraic calculus, the elements of which had, in all probability, been taught by some of the latter school of Alexandria to the Arabs, was revived and carried to a greater perfection and range of applicability by the successive labours of Cardan, Newton, Leibnitz, Euler, and others. Wedded to geometrical analysis and synthesis, and both to astronomical observation and mechanical experiment, it has opened up to us new worlds, and given a more perfect command of the elements of that which we inhabit. The astounding nature of the discoveries in science which, throughout this period, came huddling with hot haste upon each other, were of themselves sufficient to excite that gaping attention of the many, which, in other ages, was confined to the poet or the romancer. The imaginative writers fell into the back ground. Even such as continued to cultivate the *belles lettres*, assumed a wary and subdued tone. They stood like scholars craving indulgence for their amusements from the philosophers, who were now lords of the ascendancy. The wings of the muse were clipped, the hippognoff could no longer soar when anatomists were ready to depone to the impossibility of its structure, and the physical enquirer to confine the limits of the atmosphere that was to bear it up. Poetry was a tolerated and refined amusement or pastime: it was elegant but timid, and consequently feeble. Boileau in France, Pope in England, Metastasio in Italy, and Gesner in Germany, are the poetical types of this era. Under another department of intellectual exertion, however, the progress of physical science had a more favourable influence. Descartes, in his "Dissertatio de Methodo," gives us the result of a scrutiny of his own knowledge; the grounds on which it rested, and the powers of his intellect, which he established, preparatory to devoting himself to scientific pursuits. This application of the method of observation to intellectual phenomena, has been followed up by Locke, Barclay, Hume, Reid, and Kant (I name but the heads of the principal schools), and the results, if not very voluminous in themselves, have been invaluable; first, inasmuch as they have led to greater precision of thought and expression, and have ended in striking out new paths of enquiry in morals, politics, and jurisprudence. Hobbes was the first to employ the results of a similar self-scrutiny as the basis of a political system. His Leviathan starts from a classified enumeration of the elementary qualities of man as an individual. From these he infers the conduct of man in society, and the necessity of a government; and from these again, the most suitable kind of government. The new science of international jurisprudence, promulgated by Grotius, was systematized and extended by the application of a process to it similar to that which Hobbes had applied to political enquiry. Some disciples of this school went farther, and attempted to establish upon similar grounds a law of nature as the foundation of municipal law. They failed, but chiefly on account of the incompetency of those who undertook the experiment. In the course of their metaphysical and political investigations, both Hobbes and Locke had touched incidentally upon scientific ethics. Shaftesbury discoursed upon the subject more at large, but discursively. Spenser had entered into some investigations, which, on account of their abstract nature, have been much misconceived and misrepresented. But our countrymen, Hutchison and Smith, did most, perhaps, to establish those views in moral science which prevailed to the close of the period now under review. The last-mentioned opened up in his "Wealth of Nations" a new and curious field of enquiry.

From the foregoing recapitulation, it must be evident that the tendency of the science of this period was to exercise the judgment in undue preponderance to all the other qualities of the mind, and to accumulate details to an amount amid which the mind got bewildered. Science invigorates the faculties of him who actively pursues it; it merely liberalises the disposition of him who rests contented with ascertaining the results. The science of this age was, from its eminently practical character, calculated to arrest the attention of a wider public than that of any age that preceded it. There was a homeliness about it even to affectation: it sought to be a fire-side companion. This had its good effects and its bad; for while it imparted a higher dignity to mere mechanical pursuits, it likewise induced a habit of reducing everything to a man's own level. Men ceased to have faith in anything greater than themselves. Another phasis of this disposition showed itself in a strange mixture of scepticism and credulity. The prevailing tone of illustrating the principles of nature by reference to their action in familiar and trifling instances had blinded men's susceptibility to the sentiment of spiritual greatness, while the unexpected and startling discoveries daily made in experimental science prepared them to receive with almost implicit belief the strangest reports in this way. It is this which accounts to us for the grovelling tone of morals, the ridicule of all enthusiastic or imaginative flights, combined with ready belief in all the *quackeries of Mesmerism.* Man is born with an instinctive propensity to find pleasure in the contemplation of the supernatural, and if he is laughed out of his reverence for the Divinity, this appetite will find meat in falling down and worshipping the most repulsive and imbecile superstitions. Some of the men who, in the brilliant days of Parisian philosophism, were the most vaunting professsors of Atheism, were the gulls and dupes of Cagliostro.

It is the reflecting and investigating few who give the tone to an age's intellect: it is its institutions that give the tone to its moral sentiments. During the period now in question, men had become more habituated to legal settled governments within the different states. And towards its close they became familiar with the idea of subjecting even the lawless work of war to a code of its own. Men were, however, tamed rather than made just. A more energetic police repressed many crimes; men contracted the habit of venting their spite in law-pleas instead of blows, but they continued ignorant of law. They were thus placed at the mercy of the lawyers; and these, although a professional sense of honour tied them down to the letter, knew not, and cared not for the spirit. But the circumstances of society further aggravated this evil. With the concentration of the executive power in the hands of the sovereign, in the great majority of European states, the reality (and what is perhaps of more importance to the vain, the appearance) of influence had centered in the court. Whoever would climb to the top of the profession must make that the sphere of his exertions. The courtly spirit now began to be engrafted on the patrician. Old descent was ever, in the eyes of nobles, of little avail unaccompanied by court favour. Expenses were incurred by courtly rivalry to excel each other in outward show, which forced even the haughty *noblesse* to intrigue for the emoluments of office, and kings themselves to devise ways more ingenious than honourable to procure money for their pleasures. The centralized power was converted into an engine for extracting money from the subject, which was dissipated in show: it might be tasteful or the reverse, harmless in itself or dissolute, but which was unconnected with the real business of the state. Dissatisfaction among the masses was the result, and this led in turn, as kings and nobles now made common cause, to increase of the power of the sovereign. Society became divided into two classes: the privileged, consisting of courtiers and their friends; the unprivileged, who had no influence in that sphere. The habit of observance of the laws, not being united with knowledge of the law, was increasing. Mere external conformity was thought enough; and as ambition tied the lawyers to the court, it was soon brought about that there was one law for the rich and powerful, and another for the poor and friendless. The courts of law became little better than mere engines of state.

The sanction of religion soon became as unable to check the progress of demoralization as the progress of law. Its name had been made the war-cry of faction, until men became doubtful of its existence. The so-called philosophical spirit weakened its influence still further. Its small pride of scepticism was gratified with detecting the inconsistencies and absurdities of sectarians; it could not elevate itself to the conception of the sublime idea after which they were groping in blindness and error. To complete the evil, the courtier spirit broke into and further contaminated the ranks of the church. Whoever would thrive in it must seek for court patronage, must adapt himself to court humours, work at debauchery, affect a superiority to what was considered the grimace of his order. That last and deepest injury had been done to religion which is only experienced "when at the altar the priest turns atheist."

It is in Paris that we are to seek for the most perfect specimen of the state of society engendered under such auspices. Paris was then, even to a greater extent than it is now, the capital of Europe: its fashions were eagerly copied everywhere—among the courtly classes of Spain, Italy, and Germany. Even England caught the contagion under the Restoration, which endured from 1660 to 1688, and was but partly cured by that eruption. Paris was the original, the rest but copies more or less perfect. And what was Paris? There tyranny had been reduced to a system, of which the courts of law were the engines. The family relations, sanctioned by religion, were violated in every respect with impunity, so that a certain regard to appearances was preserved. The in-

tellect was cultivated as an elegant luxury, not so apt to pall as the mere pleasures of sense. Of science little was imbibed beyond that sceptical tone which reconciled men to the habitual violation of duty by teaching them that such practices were proofs of a daring spirit superior to prejudice. The frivolous pursuits of the court communicated a frivolity, not merely to its frequenters, but to all their apes in less distinguished spheres. The expenses of the courtiers and their imitators, by keeping them at once needy and luxurious, made them mean as well as unprincipled. Private fortunes and the national resources were squandered with equally lavish hands. There was a sentiment of virtue, for the human soul can never be entirely corrupted, and soothes itself by the contemplation and acknowledgment of the beauty of the virtue it does not possess. But the practice of virtue would have been sought for in vain, for that presupposes habits of self-controul. And in this fool's paradise the imbecile and dissolute dreamed on in slumberous security. Poverty was at the door, but they saw it not, or heeded not. The famished and degraded multitude were crushed to madness in the wine-press of oppression; their deafening groans were not listened to. The industrious classes, in whom hard work and the necessity of prudence had kept alive an every-day virtue, and who caught the reflection of the lights of knowledge, were alienated—they cared not for it. The pillars of the social edifice, all fairly gilded and seemingly proportioned as they were, were rotten and about to crumble down—still they trifled unthinkingly. It is an awful picture of fool-hardy confidence: the imbecile court of France, reposing in the arms of a lunatic nation, immediately previous to the outburst of the revolution. And to a greater or a less degree, the position of the French was the position of European society.

PRINCIPLES OF ALGEBRA.

CHAPTER XII.

RATIO, PROPORTION, AND PROGRESSION.

Ratio is the relation which quantities of the same kind bear to each other in respect to magnitude.

The *difference* in magnitude between the quantities compared is called their *arithmetical ratio;* and the *quotient* arising from the division of the quantities compared is called their *geometrical ratio.* Thus, if a and b be compared, $a-b$ expresses their arithmetical ratio, and $\frac{a}{b}$ their geometrical ratio.

When the term ratio is used without any qualification, it denotes a *geometrical ratio,* and to prevent confusion, the simple term *difference* is used to denote an *arithmetical ratio.* In what follows, *ratio* always means *geometrical ratio.* Also, to prevent the too frequent repetition of the term, two dots are usually placed between the quantities to represent their ratio, thus $a : b$ signifies the ratio of a to b, and a and b are called the *terms* of the ratio, a is called also the *antecedent,* and b the *consequent* of the ratio.

When the antecedents and consequents of any number of ratios are respectively multiplied together, the ratio of the products is said to be compounded of the preceding ratios. Thus, the product of the antecedents of the ratios $a : b$ $c : d$, $e : f$, is $a c e$, and the product of their consequents $b d f$; $\therefore$ $a c e : b d f$ is the *compound ratio,* and expresses the *sum* of the ratios given.

When a ratio is compounded with itself $n-1$ times, the resulting ratio is called the *nth ratio* of the primitive. Thus the ratio of $a : b$ compounded with itself *once,* gives the ratio of $a^2 : b^2$, *twice* gives $a^3 : b^3$, *thrice* gives $a^4 : b^4$, and these ratios are called respectively, the *duplicate,* the *triplicate,* and the *quadruplicate,* ratios of their primitive $a : b$. Similarly, $a^{\frac{1}{2}} : b^{\frac{1}{2}}$ expresses the *subduplicate,* and $a^{\frac{1}{3}} : b^{\frac{1}{3}}$, the subtriplicate ratios of $a : b$; and $a^{\frac{3}{2}} : b^{\frac{3}{2}}$ is termed the *sesquiplicate* ratio of $a : b$, because it is compounded of the subduplicate and primitive ratios.

The sum of any number of ratios, such, that each antecedent is the same as the preceding consequent, as $a : b$; $b : c$, $c : d$, is the ratio of the first antecedent to the last consequent. For, if the given ratios be expressed, $\frac{a}{b}$, $\frac{b}{c}$, $\frac{c}{d}$, then their sum is $\frac{abc}{bcd}=\frac{a}{d}$, that is, $a : d$.

If the terms of a ratio are both multiplied or both divided by the same quantity, the ratio remains unchanged. Hence ratios may be compared by reducing the fractions which express them to a common denominator.

Proportion.

Proportion consists in the equality of ratios.

If there be four quantities, such, that the difference of the first and second is equal to the difference of the third and fourth, these quantities are said to be in *arithmetical proportion.*

Theorem.—If four quantities be in arithmetical proportion, the sum of the extreme terms is equal to the sum of the mean terms.

For let a, b, c, d, be in arithmetical proportion, then $a-b = c-d$, and adding $b + d$ to each side, there results $a + d = b + c$.

If there be four quantities, such, that the ratio of the first and second is the same as that of the third and fourth, these quantities are said to be in *geometrical proportion.* Thus, if $\frac{a}{b} = \frac{c}{d}$ then a, b, c, d are called *proportionals,* and their proportion is expressed $a : b : : c : d$, and read *a is to b as c is to d,* that is, "as the first term is to the second, so is the third to the fourth."

If the second and third terms of a proportion be identical, the quantity forming these terms is said to be a *mean proportional* to the other two. Thus in the proportion $a : b : : b : c$ the quantity b is a mean proportional to a and c.

A series of quantities, such, that $a : b : : b : c : : c : d$, &c., where the consequent of every preceding ratio is the antecedent of the following one, are said to be in *continued proportion.*

Theorem I.—If four quantities be proportional, the product of the extremes is equal to that of the means.

For, let $a : b : : c : d$; whence $\frac{a}{b}= \frac{c}{d}$; and multiplying each side of this equation by bd, there results $ad = bc$.

Theorem II.—If the product of any two quantities be equal to the product of any two others; these four quantities will constitute a proportion. For, let $ad = bc$, then dividing each side by bd, there results $\frac{a}{b}=\frac{c}{d}$, $\therefore a : b : : c : d$.

Theorem III. If four quantities be proportional, they will also be proportional when taken inversely.

For, let $a : b : : c : d$, then (Theor. I.) $ad = bc$, and dividing this equation by ac, there results $\frac{d}{c}= \frac{b}{a}$, $\therefore d : c : : b : a$, and $b : a : : d : c$.

Theorem IV. If four quantities be proportional, they will also be proportional when taken alternately.

For, let $a : b : : c : d$, whence $\frac{a}{b}= \frac{c}{d}$, and multiplying these equals by $\frac{b}{c}$, there results $\frac{a}{c} = \frac{b}{d}$, $\therefore a : c : : b : d$.

Theorem V. If four terms be proportional, the first term is to the second *plus* or *minus* n times the first, as the third is to the fourth *plus* or *minus* n times the third.

For, let $a : b : : c : d$, whence $\frac{a}{c}= \frac{b}{d}$; then $\frac{a}{b} \pm n = \frac{c}{d} \pm n$, that is, $\frac{a \pm bn}{b} = \frac{c \pm dn}{d}$, $\therefore a \pm bn : b : : c \pm dn : d$, where n may be any number whatever, integral or fractional. When $n = 1$, then $a \pm b : b : : c \pm d : d$.

Corollary 1, also $b : a \pm bn : : d : c \pm dn$, and $d : c \pm dn : : b : a \pm bn$, (Th. III.)

Corollary 2, also $a \pm bn : c \pm dn : : b : d$; and $b : d : : a \pm bn : c \pm dn$, (Th. IV.)

Corollary 3, since $\frac{a + bn}{b} = \frac{c + dn}{d}$, and $\frac{a - bn}{b} = \frac{c - dn}{d}$, then dividing these equals by each other, there results $\frac{a + bn}{a - bn} = \frac{c + dn}{c - dn}$, $\therefore a + bn : a - bn : : c + dn : c - dn$; and if $n = 1$, then $a + b : a - b : : c + d : c - d$, that is the sum of the two first terms is to their difference as the sum of the third and fourth terms is to their difference. And $a + b : c + d : : a-b : c - d$.

Theorem VI. If four quantities be proportional, any equimultiples, or equal powers of these quantities, will also be proportional.

Let $a =$ the first term, t the last term, n the number of terms, d the common difference, and s the sum of the series,

Then $s = a + (a + d) + (a + 2d) + (a + 3d) \ . \ . \ . \ + t$ direct.
And $s = t + (t + d) + (t - 2d) + (t - 3d) \ . \ . \ . \ + a$ inverse.

Adding, $2s = (a + t) + (a + t) + (a + t) + (a + t) \ . \ (a + t) =$ twice the sum of the progression; and as there must be n terms in this last as well as in the proposed series, and since each term is $a + t$, $\therefore \ 2s = n(a + t)$.

Hence we have the following expressions :—

From Theorem III. . . . $t = a \pm (n - 1) d$ . . . (A)
From Theorem IV. . . . $s = \frac{1}{2} n (a + t)$ . . . . (B)

And these are evidently quite sufficient to enable us to determine any two of the quantities a, d, n, s, t, when the other three are given.

Examples.—1. Required the sum of the progression 5, 15, 25, 35, ... continued to 60 terms, and the value of the last term.

Here $a = 5$, $d = 10$, $n = 60$, which being substituted in Equation (A) gives $t = a + (n - 1) d = 5 + (60 - 1) 10 = 595$, the last term.

$$\text{Equation (B) gives } s = \frac{n(a + t)}{2} = \frac{60 (5 + 595)}{2} = 18000, \text{ the sum of the series.}$$

2. Given the sum of a decreasing arithmetical progression 150, the first term 12, and the common difference $\frac{1}{2}$, to find the last term and the number of terms.

Here $s = 150$, $a = 12$, and $d = \frac{1}{2}$, then by substitution

$$\text{Eq. (A)}, \quad t = 12 - (n - 1) \tfrac{1}{2} = 12\tfrac{1}{2} - \tfrac{1}{2}n \quad . \ . \ . \ . \ (1)$$

$$\text{Eq. (B)}, \quad 150 = \frac{n (12 + t)}{2} = \frac{n (24\frac{1}{2} - \frac{1}{2}n)}{2} \quad . \ . \ . \ (2)$$

Solving this equation, there results $n = 25$ or 24, and substituting this value of n in equation (1) there results $t = 0$ or $\frac{1}{2}$.

3. Given the first term of an arithmetical progression $\frac{1}{10}$, the last term 1, and the number of terms 6, to find the intermediate terms.

$$\text{Here } a = \frac{1}{10},\ t = 1, \text{ and } n = 6, \text{ to find } d.$$

$$\therefore \text{ Eq. (A) becomes, } 1 = \frac{1}{10} + (6 - 1) d, \text{ whence } d = \frac{9}{50}$$

$$\text{Then } \frac{1}{10} + \frac{9}{50} = \frac{5 + 9}{50} = \frac{14}{50} = \frac{7}{25} = \text{the 2nd term, or first mean.}$$

$$\frac{7}{25} + \frac{9}{50} = \frac{14 + 9}{50} = \frac{23}{50} = \frac{23}{50} = \text{the 3rd term, or second mean.}$$

$$\frac{23}{50} + \frac{9}{50} = \frac{23 + 9}{50} = \frac{32}{50} = \frac{16}{25} = \text{the 4th term, or third mean.}$$

$$\frac{16}{25} + \frac{9}{50} = \frac{32 + 9}{50} = \frac{41}{50} = \frac{41}{50} = \text{the 5th term, or fourth mean.}$$

In this manner may be inserted any proposed number of *arithmetical means* between two given numbers.

4. Given the progression 1, 3, 5, 7, ... continued to 101 terms, to find the last term and the sum of the series. Ans. $t = 201$, and $s = 10201$.

5. Given the first term 1, the difference 2, and the last term 201, to find the sum of the series and the number of terms. Ans. $s = 10201$ and $n = 101$.

6. Given the sum of an increasing arithmetical series 10201, the first term 1, and the number of terms 101, to find the last term and the difference. Ans. $t = 201$, $d = 2$.

7. Given the sum of an increasing arithmetical series 10201, the last term 201, and the number of terms 101, to find the first term, and the difference. Ans. $a = 1$, $d = 2$.

8. Given the sum of an increasing arithmetical series 10201, the last term 201, and the difference 2, to find the first term, and the number of terms. Ans. $a = 1$, $n = 101$.

9. Given the sum of an increasing arithmetical series 10201, the first term 1, and the difference 2, to find the last term and the number of terms. Ans. $t = 201$, $n = 101$.

10. Required the sum of the natural numbers 1, 2, 3, 4, 5, ... continued to 1000 terms, and the value of the odd numbers in the series. Ans. 500500 and 25250.

11. Required the sum of the series 15, 11, 7, 3,—1,—5 . . . continued to 20 terms, and the value of the last term. Ans. $s = -460$, $t = -61$.

12. The first term of a decreasing arithmetical series is 10, the common difference $\frac{1}{3}$, and the number of terms 21. Required the sum of the series. Ans. $s = 140$.

13. Given the sum of an arithmetical series 54, the first term 14, and common difference —2, to find the number of terms. Ans. 9 or 6.

14. Required five arithmetical means between 1 and 3. Ans. $1\frac{1}{3}$, $1\frac{3}{3}$, 2, $2\frac{1}{3}$, $2\frac{2}{3}$.

15. Required six arithmetical means between 0 and 1. Ans. $\frac{1}{7}$, $\frac{2}{7}$, $\frac{3}{7}$, $\frac{4}{7}$, $\frac{5}{7}$, $\frac{6}{7}$.

16. Required six arithmetical means between —1 and 1. Ans. $-\frac{5}{7}, -\frac{3}{7}, -\frac{1}{7}, \frac{1}{7}, \frac{3}{7}, \frac{6}{7}$.

17. Required the several terms of an equidifferent series, whose extremes are —10 and $\frac{1}{10}$ and the number of terms six. Ans. $-10, -7\frac{49}{50}, -5\frac{24}{25}, -3\frac{47}{50}, -1\frac{23}{25}, -\frac{1}{10}$.

Geometrical Progression.

A geometrical progression is a series of quantities, of which each term is formed by multiplying the one immediately preceding it, by a constant quantity called the *ratio.* Thus if a be the first term, and r the ratio, the following expression is a geometrical progression :—

$$a,\ ar,\ ar^2,\ ar^3,\ ar^4,\ ar^5,\ \ . \ . \ . \ \ ar^{n-1}$$

where a and r may be any numbers whatever, integral or fractional, positive or negative.

In this series, since the exponent of r begins with the second term, it is evident that, if the series be continued to n terms, the exponent of r in the last term will be $n-1$, and the last term itself, ar^{n-1}, as expressed above.

Problem.—To find the sum of n terms of a geometrical progression,

Let $s = a + ar + ar_2 + ar^3 + \ . \ . \ + ar^{n-2} + ar^{n-1}$ . . (1)

Multiply both sides of this equation by r, and it becomes

$$rs = ar + ar^2 + ar^3 + ar^4 \ \ . \ . + ar^{n-1} + ar^n \quad . \ . \ (2)$$

Substract equation (1) from equation (2) and there results

$$(r - 1) s = a (r^n - 1); \text{ whence } s = \frac{a (r^n - 1)}{r - 1} \quad . \ . \ (A)$$

Again, subtract equation (2) from equation (1) and there results,

$$(1 - r) s = a (1 - r^n); \text{ whence } s = \frac{a (1 - r^n)}{1 - r} \quad . \ . \ . \ (a)$$

Now if $t = ar^{n-1}$, then $rt = ar^n$, and by substitution

$$\text{Equation (A) becomes} \ . \ . \ s = \frac{rt - a}{r - 1} \quad . \ . \ . \ . \ (B)$$

$$\text{Equation } (a) \text{ becomes} \ . \ . \ s = \frac{a - rt}{1 - r} \quad . \ . \ . \ . \ (b)$$

Note 1.—Since the equations (A) and (B), or (a) and (b), express the relations of the five quantities a, n, r, s, t, to one another, it appears that any three of them being given, the other two may be found by elimination; but it must be remarked, that when it is required to find r from a, n, s given, or from n, s, t given, r is obtained in an equation of the nth degree, which cannot be solved generally, and n being found only as an exponent, can only be determined by means of logarithms.

Note 2.—The equations (a) and (b) are most convenient for calculation when r is less than 1.

Examples.—1. Required the sum and first term of a geometrical progression, of which the ratio is 2, the last term 1536, and the number of terms 10.

Here are given $t = 1536$, $n = 10$, and $r = 2$, to find s and a.

$$\text{Then Eq. (A) } s = \frac{a (r^n - 1)}{r - 1} = \frac{a (2^{10} - 1}{2 - 1} \quad \therefore \ s = 1023\,a.$$

$$\text{And Eq. (B) } s = \frac{rt - a}{r - 1} = \frac{2 \cdot 1536 - 1}{2 - 1} \quad \therefore \ s = 3072 - a.$$

Hence $1023a = 3072 - a$; whence $a = 3$.
And $s = 3072 - a$, whence $s = 3069$.

2. Required the sum of nine terms and the ratio of a geometrical series, of which the first term is 1 and the last term $\frac{1}{6561}$.

Here are given $a = 1$, $t = \frac{1}{6561}$ and $n = 9$, to find r and s.

$$\text{Then Eq. } (a) \ . \ . \ . \ s = \frac{a (1 - r^n)}{1 - r} = \frac{1 - r^9}{1 - r}$$

$$\text{And Eq. } (b) \ . \ . \ . \ s = \frac{1 - rt}{1 - r} = \frac{1 - \frac{r}{6561}}{1 - r}$$

For, let $a : b :: c : d$, whence $\frac{a}{b} = \frac{c}{d}$, and since $\frac{am}{bn} = \frac{cm}{dn}$ and $\frac{a^n}{b^n} = \frac{c^n}{d^n}$ $\therefore am : bn :: cm : dn$; and $a^n : b^n :: c^n : d^n$, where m and n may denote any numbers whatever, whole or fractional.

THEOREM VII. If the corresponding terms of any number of proportions be multiplied together, or divided by each other, the resulting quantities taken in order will still be proportional.

For, let $\begin{Bmatrix} a : b :: c : d \\ e : f :: g : h \end{Bmatrix}$ whence $\begin{Bmatrix} \frac{a}{b} = \frac{c}{d} \\ \frac{e}{f} = \frac{g}{h} \end{Bmatrix}$ And multiplying the corresponding sides of these equations together, there results $\frac{ae}{bf} = \frac{cg}{dh}$. $\therefore ae : bf :: cg : dh$.

Again, (Theorem I.) $ad = bc$, and $eh = fg$, hence $\frac{ad}{eh} = \frac{bc}{fg}$

$\therefore$ (by Theorem II.) $\frac{a}{e} : \frac{b}{f} :: \frac{c}{g} : \frac{d}{h}$

THEOREM VIII. In any number of equal ratios, the first antecedent is to its consequent as the sum of all the antecedents is to the sum of all the consequents.

For, let $a : b :: c : d :: e : f :: g : h$, whence $\frac{a}{b} = \frac{c}{d} = \frac{e}{f} = \frac{g}{h}$

$$\begin{aligned} \text{Then } ab &= ba \\ ad &= bc \\ af &= be \\ ah &= bg \\ \hline a(b + d + f + h) &= b(a + c + e + g) \\ \therefore \quad \frac{a}{b} &= \frac{a + c + e + g}{b + d + f + h} \end{aligned}$$

Hence $a : b :: a + c + e + g : b + d + f + h$

Corollary 1, $a : b :: a - c + e - g : b - d + f - h$

Corollary 2, Also, in any number of proportions, where the ratios of the two first and two last terms are respectively the same in each, the sums of the corresponding terms are in proportion.

Problems.—1. Given the product of two numbers, 24, and their difference to their sum as 5 to 11, to find the numbers.

Let $x =$ the one number, and $y =$ the other.

$$\text{Then } xy = 24; \therefore y = \frac{24}{x}$$

And $x - y : x + y :: 5 :: 11$, per question.

By Theor. V. $2x : 2y :: 16 : 6$.

That is . . . . . $x : y :: 8 : 3$.

By Theor. I. $3x = 8y = 8 \frac{24}{x}$, $\therefore x = 8$, and $y = 3$

2. To divide the number 20 into two parts, which shall be to each other in the duplicate ratio of 3 : 1; and to find a mean proportional to these parts.

Let $x =$ the one part, and $20 - x =$ the other.

Then per question, $x : 20 - x :: 3^2 : 1^2$.

By Theor. I. . . . , $x = 180 - 9x$; whence $x = 18$.

The parts are therefore 18 and 2, and by Theor. III. a mean proportional between 18 and 2, is $\sqrt{18 \times 2} = 6$.

3. To find three numbers in continued proportion, such, that the sum of the first and second multiplied into that sum *minus* the third number shall $= 90720$; but the former difference multiplied into the sum of all three shall $= 117936$.

Let x, y, and z, denote the numbers.

$$\text{Then } \begin{Bmatrix} (x + y)(x + y - z) = 90720 \\ (x + y + z)(x + y - z) = 117936 \\ x : z :: z : y, \text{ that is, } xy = z^2 \end{Bmatrix} \text{per question.}$$

By Theo. VII. $x + y : x + y + z :: 90720 : 117936$

By Theo. V. $x + y : z :: 90720 : 27216 :: 10 : 3$

By Theo. I. and reducing $x + y = \frac{10z}{3}$

Squaring both sides, $x^2 + 2xy + y^2 = \frac{100z^2}{9} = \frac{100xy}{9}$

Let $x = vy$, then $v^2y^2 + 2vy^2 + y^2 = \frac{100vy^2}{9}$

And $v^2 + 2v + 1 = \frac{100v}{9}$, $\therefore v = 9$.

Now $x + y = \frac{10z}{3}$, but $x = vy = 9y$,

$$\therefore 9y + y = \frac{10z}{3} \text{ and } y = \tfrac{1}{3}z$$

And $x + y = \frac{10z}{3}$, but $y = \frac{1}{3}z$

$$\therefore x + \tfrac{1}{3}z = \frac{10z}{3} \text{ and } x = 3z$$

Again $(x + y)(x + y - z) = (3z + \frac{1}{3}z)(3z + \frac{1}{3}z - z) = 90720$; $\therefore z = 108$

Then $y = \frac{1}{3}z = \frac{108}{3} = 36$; and $x = 3z = 3 \times 108 = 324$

4. To divide a line of 20 inches into two parts, such, that the greater shall be to the lesser :: 3 : 2. Ans. 12 and 8.

5. To find two numbers, such, that their sum shall be to their difference as 13 to 5, and the square of the lesser *plus* the greater $=25$. Ans. 9 and 4.

6. To divide 2000 guineas between A and B in the duplicate ratio of 5 : 3. Ans. A's share £1529 8s. $2\frac{3}{4}$d., and B's share £670 11s. $9\frac{1}{4}$d.

7. To find a number, such, that if 3, 8, and 17 be severally added thereto, the first sum shall be to the second as the second to the third. Ans. $3\frac{1}{4}$.

8. To find two numbers, such, that their sum shall be 60, and their product : sum of their cubes :: 2 : 180. Ans. 20 and 40.

9. To find two numbers which are to each other in the duplicate ratio of 4 : 3, and to which 24 is a mean proportional. Ans. 32 and 18.

10. If $(a + x)^n : (a - x)^2 :: x + y : x - y$, show that $a : x :: \sqrt{(2a - y)} : \sqrt{y}$.

11. If $x : y$ in the duplicate ratio of $a : b$, and $a : b :: \sqrt[3]{(c + x)} : \sqrt[3]{(a + y)}$, show that $bx = cy$.

12. To find three numbers in continued proportion, such that their sum shall be 74, and the sum of their squares 1924. Ans. 32,24 and 18.

13. To find four numbers in geometrical proportion, such that the sum of the first and third $= 148$, and the sum of the second and fourth $= 888$. Ans. 4, 24, 144, and 864.

14. To find two numbers, such, that their sum, difference, and product, may be as the numbers s, d, and p respectively. Ans. $\frac{2p}{s + d}$ and $\frac{2p}{s - d}$

ARITHMETICAL PROGRESSION.

An arithmetical progression is a series of quantities which either *increase* or *decrease* from term to term by a *common difference*, as 1, 3, 5, 7, 9, . . . and 100, 98, 96, 94, . . .

If a be the first term of an arithmetical progression, and d the common difference, then will the successive terms of an *increasing* series be a, $a + d$, $a + 2d$, $a + 3d$, $a + 4d$, . . . and the terms of a *decreasing* series, a, $a - d$, $a - 2d$, $a - 3d$, $a - 4d$, . . .

Theorem I. If any *odd* number of terms be in arithmetical progression, the sum of the extreme terms is equal to twice the middle term.

For let a, $a + d$, $a + 2d$ be the terms of the progression, then $a + (a + 2d) = 2(a + d)$.

Theorem II. In any series of quantities in arithmetical progression, the sum of the two extreme terms is equal to the sum of any two terms equally distant from the extremes.

For let a, $a + d$, $a + 2d$, $a + 3d$, $a + 4d$ be the progression, then $a + (a + 4d) = (a + d) + (a + 3d) = 2(a + 2d)$.

Theorem III. In any increasing arithmetical progression, the last term is equal to the first term *plus* the product of the common difference and the number of terms *less* one; but if the progression be a decreasing one, the last term is equal to the first term *minus* that product.

Let the increasing series be a, $a + d$, $a + 2d$, $a + 3d$, . . . and the decreasing series, a, $a - d$, $a - 2d$, $a - 3d$, . . Now, since the coefficient of d in the *second* term is 1, in the *third* term 2, in the *fourth* term 3, and so on, it follows that if the number of terms be denoted by n, the coefficient of d in the nth or last term will be $n - 1$; and the last term itself will be $a + (n - 1)d$ when the series increases, and $a - (n - 1)d$ when the series decreases.

Theorem IV. The sum of any series of quantities in arithmetical progression is equal to the sum of the extreme terms multiplied by half the number of terms.

$$\text{Hence } \frac{1 - r_9}{1 - r} = \frac{1 - \frac{r}{6561}}{1 - r}, \text{ whence } r^8 = \frac{1}{6561}$$

$$\therefore r = \sqrt{\sqrt{\sqrt{\tfrac{1}{6561}}}} = \tfrac{1}{3}$$

$$\text{And } s = \frac{1 - r^9}{1 - r} = \frac{1 - \frac{1}{19683}}{1 - \frac{1}{3}} = \frac{(\frac{19683 - 1}{19683})3}{3 - 1}$$

$$\therefore s = \frac{9841}{6561} = 1\tfrac{3280}{6561}$$

Problem. To find the sum of an infinite series, decreasing in geometrical progression.

The general expression for the sum of n terms of a geometrical progression whose ratio (r) is a proper fraction, is $s = \dfrac{a - ar^n}{1 - r}$, which may be put under the form

$$s = \frac{a}{1 - r} - (\frac{a}{1 - r})\, r^n$$

But since r is a proper fraction, r^n is less than unity, and the greater the number n, the smaller will be the quantity r^n; consequently when the number of terms is *indefinitely great* and the series decreasing, r^n is *indefinitely small*. Hence if $n = \infty$ then will $r^n = 0$, and the above expression will obviously become

$$s = \frac{a}{1 - r} \quad . \quad . \quad . \quad (C)$$

Example.—Required the sum of $1 + \frac{1}{3} + \frac{1}{9} + \frac{1}{27} +$ &c. to infinity.

Here $a = 1$ and $r = \frac{1}{3}$, $\therefore s = \dfrac{1}{1 - \frac{1}{3}} = \dfrac{3}{3 - 1} = 1\frac{1}{2}$, the sum required.

Note.—Strictly speaking, $\dfrac{a}{1 - r}$ is the *limit* of $\dfrac{a\,(1 - r^n)}{1 - r}$ and approaches more nearly to perfect accuracy as the number of terms increases; for by actual division $\dfrac{a}{1 - r} = a + ar + ar^2 + ar^3 +$ &c. *ad infinitum;* consequently the error which would be committed in the foregoing example by taking n equal to any finite number may be determined by the quantity

$$(\frac{a}{1 - r})\, r^n = 1\tfrac{1}{2}\, (\tfrac{1}{3})^n = \frac{1}{2 \cdot 3^{n-1}}$$

Thus, if $n = 6$, then $\dfrac{1}{2.3^{n-1}} = \dfrac{1}{2.3^5} = \dfrac{1}{486}$ too much.

And if $n = 11$, then $\dfrac{1}{2.3^{n-1}} = \dfrac{1}{2.3^{10}} = \dfrac{1}{118098}$ too much.

Theorems, relating to Numbers in Geometrical Progression.

I. In any geometrical progression the product of the first and last terms is equal to the product of any two others equally distant from the extremes, and to the middle term if the number of terms be odd.

II. In any geometrical progression, the square of any term divided by the preceding term gives the following term.

III. Quantities in geometrical progression are also in continued proportion; for $a : ar :: ar : ar^2 :: ar^2 : ar^3 ::$ &c.; and their *sums* or *differences* are also in continued proportion, for $ar \pm a$, $ar^2 \pm ar$, $ar^3 \pm ar^2$, &c., or $ar \pm a$, $(ar \pm a)\, r$, $(ar \pm a)\, r^2$, &c., is a geometrical progression, whose first term is $a \pm a$, and ratio r.

IV. In every geometrical progression, the first term is to the second, as the sum of all the terms diminished by the last is to the sum of all the terms diminished by the first; that is $a : ar :: s - ar^{n-1} : s - a$.

TERMS USED IN MECHANICS.

I.—EFFICIENCY—LABOURING FORCE—POWER—DUTY.

Scarcely had mechanics been brought under the cognizance of mathematical investigation when a dispute arose respecting the measure of the force of a body in motion—a dispute which for half a century was conducted with more vehemence and acrimony than might be supposed incident to the nature of an abstract subject, and which "was rather dropt than ended, to the no small discredit of mathematics, which has always boasted of a degree of evidence inconsistent with debate that can be brought to no issue."* On one side it was contended that the true measure is found by multiplication of the weight of the body into its velocity ($W \times v$): while on the other it was affirmed with equal confidence that the proper measure is the product arising from the weight multiplied into the velocity squared ($W \times v^2$) The former definition ($W \times v$) mainly supported by comparison of inertiæ, and the relations of bodies to a common centre of gravity in planetary systems, was most commonly received as the more simple and consistent. Still the question remained undecided, and adverting to the collision of elastic bodies, and that property of motion known as the principle of *vis viva* there seemed to be equal argument in favour of the definition ($W \times v^2$).

At length it was fortunately observed that the different properties indicated by these two functions were not in reality at variance with each other, and the terms *momentum* and *impetus* with their synonymes, reconciled all opinions, and removed the basis of the dispute. It was further observed that neither impetus or momentum have much to do with practical mechanics, since neither of these functions measures directly the efficiency developed in ordinary machines. The criterion of their efficiency is the force multiplied by the space through which it acts ($F \times s$); and the effect thus developed, measured in the same way, has been appropriately termed *duty*—a term first introduced by Watt in ascertaining the comparative value of his engines, when he had assumed as a dynamical unit a pound weight raised one foot high.† This definition is founded on the manifest assumption that the resistance remaining the same in every new point of space, the pressure must likewise be exerted afresh at every point through which the resistance is overcome. This does not directly apply to the case of a body projected by an impulsive force, for then the body ascends, supposing the impulse to be upwards, through a certain space, proportioned to the force accumulated in the body, in conformity with the laws of motion; but if a body be raised slowly by a rope, we cannot for an instant relax our exertion, for if we do, the body immediately begins to descend unless prevented by some special contrivance, in obedience to the law of gravity; and during the ascent we find that a new pressure is necessary to draw the body through every particle of space. Similarly, if a certain amount of exertion be requisite to saw through an inch of a uniform block, it will require an equal exertion to saw through the next inch of the same block; and after each exertion of force the object will remain where it is and as it is, unless a new exertion of force carry on the work. Hence we conclude that the labouring force exerted is proportional to the resistance and the space conjointly, and may be measured and expressed by the product of two numbers representing these quantities, that is by ($F \times s$).

Now, as every resistance may be expressed by weight, and the overcoming of resistance may be represented by raising a weight equivalent to the resistance so measured through a vertical space, it being always supposed that the weight will remain at the point to which it is thus raised, this affords a convenient mode of estimating and of representing the mechanical efficiency of a given mechanical agency. Thus, if it requires a force of 100 lbs. to draw a carriage along a road, the power expended in drawing the carriage through 50 feet may manifestly be measured by the labouring force which would raise a weight of 100 lbs. through a height of 50 feet. Hence the labouring force is independent of the nature of the work done—which is infinitely diversified by the mechanism employed; and it is also always equal to the sum of the effects produced. Much of it may be uselessly expended in the mechanism, and therefore lost for useful

* Reid's Essay on Quantity.

† The dynamical unit termed a *horse-power* is 33000 lbs., or 528 cubic feet of water, raised one foot high in a minute. The *cheval vapeur* of the French engineers is 75 kilogrammes raised 1 metre per second; and as the metre is 3·28 feet and the kilogramme 2·2 lbs., the *cheval vapeur* will be equivalent to 31500 lbs. raised 1 foot per minute. It therefore follows that 100 English horse-power is equivalent to 105 French nearly.

purposes, and hence the value of one species of machine as compared with another—that machine being the best which transmits the highest per centage of the power applied to it. Thus, if a man's weight be 100, and he be capable of raising a weight of 90 by a single pulley and rope, the duty is to the labouring force or power as 90 to 100; or 10 per cent. of the power has been expended in overcoming the friction of the pulley and the rigidity of the rope. By diminishing the amount of these resistances the duty may be correspondingly increased; or the same weight may be raised by a less expenditure of power. What is obviously true in this case is equally true of any mechanism however complicated. Thus, if F be the pressure exerted upon the first piece of mechanism in the direction of its motion, and S the space through which it moves in any given unit of time; and if f be the pressure exerted by the last piece of mechanism upon the work, and s the space through which it moves in the same unit of time; further, if p express the amount of power necessary to overcome the friction in the mechanism itself, then, whatever be the nature or extent of the train, we have

$$f \times s + p = \mathrm{F} \times \mathrm{S}.$$

By the same reasoning, the amount of labouring force corresponding to a given space is not altered by altering the velocity of working, provided the pressures F and f remain constant. But in many cases the pressure exerted changes with the change of velocity, and accordingly the power will vary with the varying rate of working; and there may be a rate of working for which the power is a *maximum*. Thus, a water-wheel would yield no mechanical efficiency at a velocity equal to that of the water which impels it; and taking the common formula to express the horse power of a locomotive engine, viz., $(\mathrm{L} \times \mathrm{S}) \div 62{\cdot}5$ (in which L is the load in tons, and S the speed in miles per hour), it is obvious, taking the limits of L and S at the load which the engine is just capable of moving, and the speed which it would attain without any load, that the maximum of effect must lie somewhere between.

"In connexion with this subject it may be observed generally, that the conditions under which machines produce this maximum effect, may be considered either in respect of the mechanical effect which they are capable of deriving from a given exertion of the motive power, or in respect of the amount of mechanical effect which they are capable of exerting with reference to the expenditure of the impelling force. These conditions are moreover very rarely separable, so that to obtain a maximum effect in one sense, very commonly involves different conditions to those which would produce it in the other. To obtain the maximum effect from a given expenditure of motive force, the machine must be adapted to receive the greatest amount possible of the motive force, and not permit any portion of it to be expended without producing its full effect in impelling the machine. This most obviously depends upon the mechanical organs of the machine being perfectly proportioned to the forces which are to act upon them, according to the velocity, intensity, and direction of those actions, and must have reference to some particular velocity with which the motive force is required to impel the machine; but it is also equally obvious, that each kind of motive force having some particular velocity at which it can act with the greatest advantage, if we exact from the machine a higher velocity of motion than is consistent with the activity of the impelling power, we can only obtain it by a sacrifice of mechanical effect. Thus the useful effect due to animal exertion decreases rapidly as the speed increases. A horse, for instance, cannot move its limbs quicker than a certain velocity, even if it had no resistance to overcome; and it is only when working at the most advantageous speed that its mechanical effect can be valued at 33,000 lbs. raised 1 foot per minute.* On the other hand, a resistance may be opposed so great that the animal cannot move at all; and in this case, as well as in that of excessive velocity, no mechanical effect is realized. In the same manner the natural currents of wind and water are limited in the rapidity of their motions, and will act as motive forces most efficaciously when the recipients are adapted to their respective velocities; that is, when the parts of the machine to which the motion is applied act only at such velocities as to receive the whole force of the current. If the motion of the recipient be greater—should it approximate to that of the current—then a part only of the force will be realized; for the current, when it has passed from the machine will retain the same velocity as the parts upon which it acted, and consequently a motive force corresponding to that velocity, which has produced no useful effect upon the machine. In like manner, the elastic force of steam is limited in the velocity of the motion with which it can act upon the piston (in the steam engine); and in the case of the locomotive engine, the velocity corresponding to the maximum effect may be passed. It is however to be remarked that this limit is brought greatly nearer by the practical necessity there is of contracting the apertures by which the steam is admitted into the cylinder; the motive force is thereby not permitted to act freely upon the piston, but only with a limited activity; and further, that certain of the resistances—the resistance, for instance, arising from the action of the atmosphere upon the train, and of the blast pipe against the piston—increase with the velocity, so that at a certain speed, easily determined by calculation (where the data are determined), the augmented resistance becomes equal to the diminished motive force. This is the limit of velocity, for there being no preponderance of motive power, there cannot be any acceleration; and a dynamical equilibrium being established, the motion will continue uniform. Did these conditions not exist—had the steam no contracted orifices to pass through, and were there no augmentation of resistances with increased speed—then the velocity of a locomotive, and the power of steam engines generally, would be limited only by the rate of vaporisation in the boiler."†

In any moving body there is accumulated by the action of the forces whence its motion has resulted, a certain amount of power which it reproduces upon any resistances opposed to its motion, and which is measured by the effect produced upon that obstacle. It is this accumulated power which has been called *impetus* by Dr. Wollaston, and *energy* by Dr. Young, and on which the dispute respecting the measure of dynamical force was so long maintained. Thus, in a ball fired from a cannon there is an accumulated power ready to be expended upon any obstacle it may encounter in its flight; and in the water which flows through the channel of a mill-lead there is accumulated the power which is transferred (in part) to the undershot wheel. Similarly, a carriage descending an incline, if allowed to descend freely, accumulates a power sufficient to carry it a considerable distance up the next incline. In those and analagous cases, the pressure for a time exceeds the resistance, and that surplus pressure is accumulated in the moving body, and it is easily shown that in every case, the power accumulated is precisely equal to the power expended upon the body beyond that necessary to overcome the resistance opposed to its motion, a principle, indeed, which might almost be assumed as in itself evident. It is likewise evident that the power accumulated in a moving body will be the same for the same velocity, under whatever circumstances that velocity has been acquired. Whether the velocity of a ball has been communicated by projection from a steam gun, or by explosion from a cannon, or by being allowed to fall freely from a sufficient height, it matters not to the result; provided the same velocity, v, be communicated to it in all three cases, and it be of the same weight, w, the power accumulated in it, estimated by the effect it is capable of producing, is evidently the same.

To estimate the power so accumulated in a body moving with a given velocity, let us suppose that the body is projected with the velocity v in a direction opposite to gravity: by the laws of motion, it will ascend to the height h, from

* The average value of a horse is from 21000 to 22000 lbs. raised 1 foot per minute. What is known as a horse-power in mechanics is really equivalent to one and a half times the power of the animal.

† The Engineer and Machinist's Assistant, published by Blackie and Son, Glasgow.

which it must have fallen to acquire the same velocity v; there must then at the instant of projection have been accumulated in it a force sufficient to raise it to the height h; but the number of units of power requisite to raise a weight w, to a height h, is represented by the product $w \times h$, for here h represents the space s, through which the force is exerted, and therefore $w \times h$ agrees with the definition $F \times s$. Now, cause and effect being equal, $w \times h$ will likewise express the number of dynamical units accumulated in the body at the instant of projection. But since h is the height from which the body must fall to acquire the velocity v, and since* $v = \sqrt{2gh}$ by the laws of falling bodies: therefore $h = \frac{1}{2}\frac{v^2}{g}$; hence replacing h by its equivalent in the expression $w \times h$ and taking U to represent the number of dynamical units accumulated, we have

$$U = \frac{1}{2}\frac{w}{g}v^2$$

It therefore appears that the power accumulated in a moving body, however its velocity may have been attained, whatever may have been the circumstances under which that velocity was acquired, is *proportional* either to the *space* through which the moving force is exerted, or to the *square* of the velocity of the body in which such force is accumulated. "Thus a bullet moving with a double velocity will penetrate to four times the depth in a bed of clay of uniform consistence: a ball of equal size, but of one-fourth part of the weight, moving with a double velocity will penetrate to an equal depth. Thus also when the resistance opposed by any body to a force tending to break it, is to be overcome, the space through which it may be bent before it breaks being given, as well as the force exerted at every point of that space, the power of the body to break it is proportional to its weight, multiplied into the square of its velocity." And from this it follows, that to double the velocity we must apply four times the power. Thus, were it necessary to obtain a certain velocity by means of the descent of a heavy body from a height, to which we carried it by a flight of steps, we must ascend, if we wish to double the velocity, a quadruple number of steps, and this will cost four times as much labour.

In our next article on this subject, we shall endeavour to illustrate the principles here indicated by some practical examples, and clear it of that ambiguity which seems to attach to calculations founded on the measure of force.

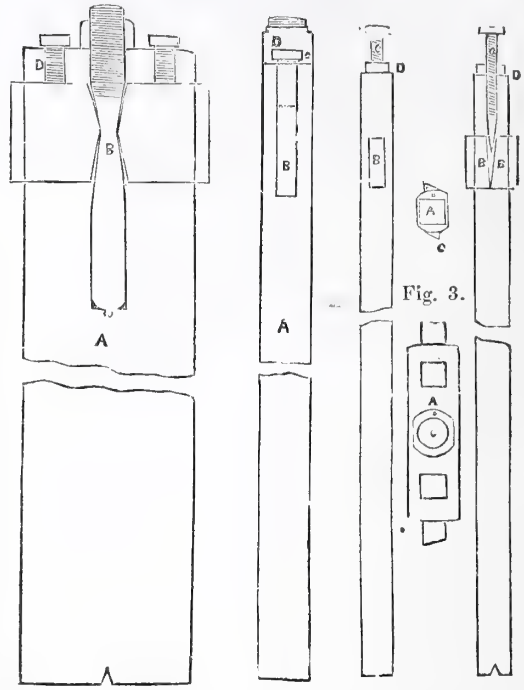
WOODCOCK'S EXPANDING DRILL.

Practical men are well aware that, after boring a few holes with an ordinary drill, the friction and wear materially reduce its size; this may be obviated, to a certain degree, by beating out the drill without the trouble of heating it. After once or twice beating, however, the metal begins to crack, and we are obliged to resort to the smith to enable it to be still more expanded when hot. This causes the workmen to lose a good deal of time, and the process is, in the end, rather expensive. Mr. Woodcock's drill presents a comparatively easy remedy for the evil, as, not only can the wear be compensated for in a simple manner, but one drill may be arranged to bore a series of different-sized holes within a certain range.

Fig. 1 is a longitudinal section of a boring bit of this kind, and fig. 2 is a side elevation of the same. It is intended to bore holes from 4 inches to $4\frac{5}{16}$, the drawing being one-fourth the actual size of the instrument.

A is a flat bar, 2 feet 6 inches long, $3\frac{1}{2}$ inches wide, and 1 inch thick; the two ends of the bar are first centered truly with the angles of the bar, which are then turned off in the lathe, as represented in the end view, Fig. 3. The upper end of A is then rounded, so as to permit it to run in a boring collar; so that by this means the hole B, may be bored true with the turned bar. The steel pin B is then fitted in very exactly, a small hole being drilled at the bottom, to allow of the escape of the air. The slot for the cutters is now marked out, and the space is drilled by fastening the bar on one angle chuck and drilling it with a vertical drill. The slot is then chipped out until the drifts, three in number, may be used—care being taken to drift them true with the turned bar.

Fig. 1. Fig. 2. Figs. 4. 5. 6.



The two cutters are shown at C C; they are fitted in so that they may be pushed in or out by hand, or they may be tapped in with a piece of wood. Each cutter is filed away a little more than the incline of the steel plug, so that they may be easily projected by it from the centre to a distance of $\frac{5}{16}$ths of an inch, or $\frac{5}{32}$ on each side. The steel plug B, has a fine thread cut on its upper end, on which the adjusting nut E, is fitted. When set to the required size, the two steel set screws D D, prevent any movement of the cutters, The steel plug being properly and truly fitted in, provides a centre for the end of the bar, so that the cutters may thus be turned true with it.

Fig. 4 is a half sized $\frac{1}{2}$ inch boring bit. For these small sizes the bars are of steel, up to 1 inch diameter, then up to $1\frac{7}{8}$ inch, they are case hardened, and from two inches and upwards, the construction is the same as in Fig. 1. In order to get the hole for the conical screw—true, three small taps are used, the tapping being effected at the same time that the hole for the collar is bored

Figs 5 and 6 are respectively a side and end view of the same drill. Previous to trial, it was fancied that the small drills would not stand well, and it is true that they will give way if not fairly used. They are not intended for roughing out a hole, but only for finishing; and so well do they answer for this purpose, that not one of them has yet given way.

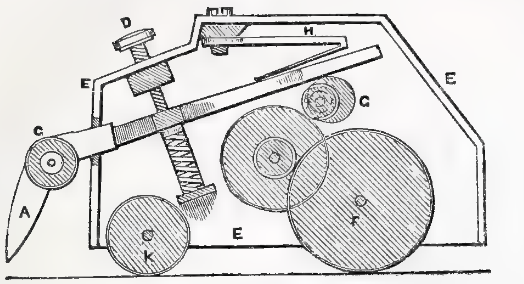
DOTTING INSTRUMENT.

As drawing dotted lines by hand is rather unsatisfactory, inasmuch as it requires considerable practice to form them correctly, the annexed instrument has been proposed as calculated to save some trouble in drawing such lines. We know of no other instrument for the same purpose, except a thing like a spur, which we consider of little value.

By referring to the following description, the mode of action may be seen. A is a steel-drawing pen, formed with an angle at c, oscillating at the point, B. C is a small eccentric wheel

* The force of gravity is, in respect of the descent of bodies near the earth's surface, a constantly accelerating force, increasing the velocity of their descent by 32·2 feet in each successive second; in like manner, if they be projected upwards, it becomes a constantly retarding force, diminishing their velocity by that quantity each successive second of time. The symbol g is commonly used to denote the number 32·2, and is so used above.

acting in its revolutions on the end of the pen, so as to press it against the paper. This wheel is connected to the roller, F, on which the machine runs, not by teeth, but by bands of



leather round the wheels, and revolves about 16 or 20 times for each turn of the roller-wheel; or, in other words, each revolution of the latter will cause the pen to make 16 or 20 dots or lines in the space of 1½ inch, or thereabouts, sufficient for most purposes. D is a small screw for raising or depressing the axis of the pen, which works in slots cut in the cover, E E. H is a small spring, to keep the end of the pen close to the eccentric wheel, and K is a small roller to steady the machine, as it is drawn along over the paper.

This machine might, perhaps, be so improved as to adapt it to the drawing of dotted circles.

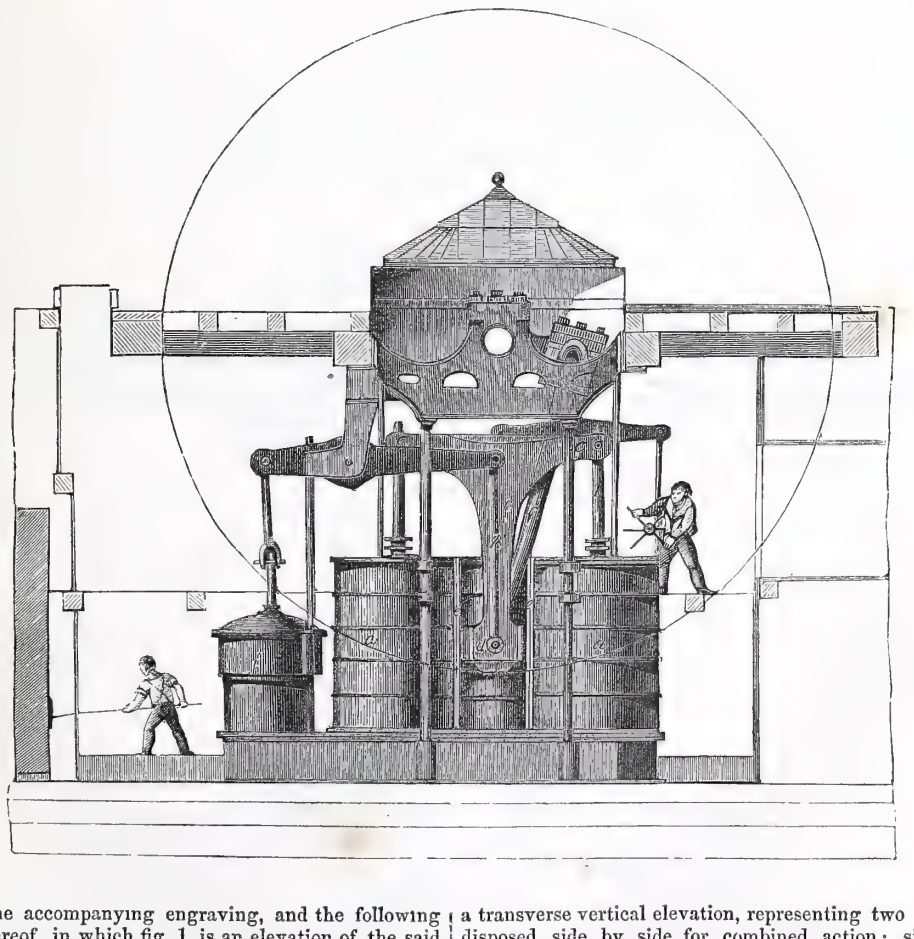
PATENT DOUBLE CYLINDER MARINE ENGINES.

BY MAUDSLAY, SONS, AND FIELD.

A MODEL of a pair of direct-acting double cylinder marine steam engines, fitted with paddle-wheels and improved feathering floats, of which we here present three engravings, was exhibited in the Crystal Palace (1851), by Maudslay, Sons, and Field, engineers, Lambeth. The improvements introduced in the construction of these engines are particularly applicable to those of the larger class, and are designed principally for the purpose of producing and applying a greater amount of steam power than has hitherto been available within a given space or area on shipboard, and also for obtaining a greater length of stroke and connecting-rod in a given height, than can be obtained (in a direct-action engine) by any other means, and the lower end of the connecting-rod guided without any lateral pressure on the pistons or piston-rods.

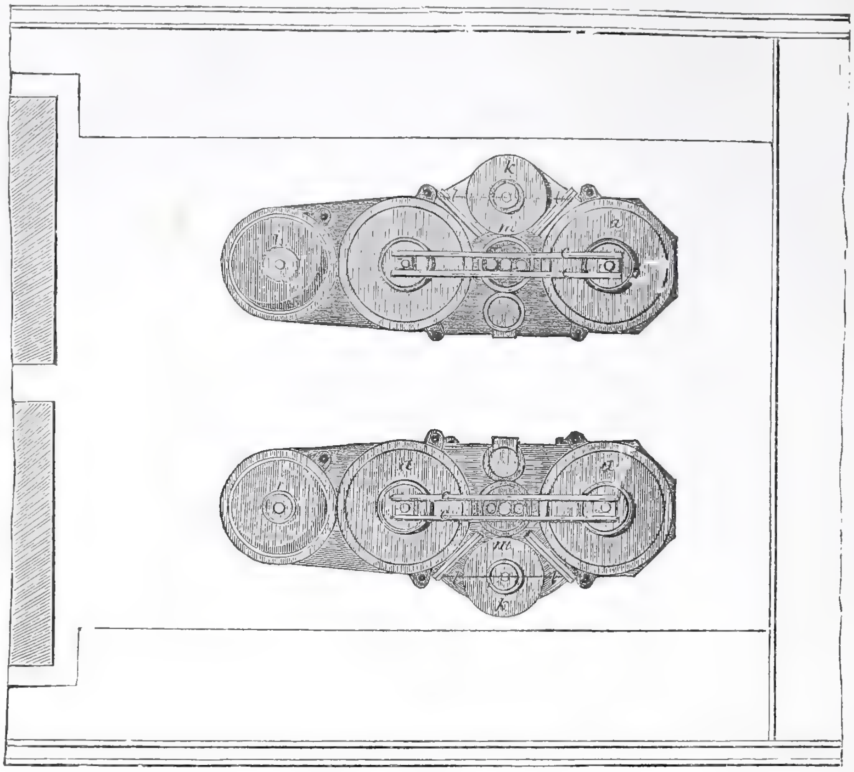
The improvements consist in adapting two steam cylinders (each of half the area necessary for the intended power) to one engine, placing them so far apart as to leave a space between, for the connecting-rod and the lower end of a T-shaped cross-head, to which the connecting-rod is attached, to work in and be guided; the piston-rods being attached to the horizontal extremities of the T-shaped cross-head, and moving up and down simultaneously with it and with each other, whereby the combined action of both pistons is applied to one crank of the paddle shaft.

These improvements will be more fully understood by a



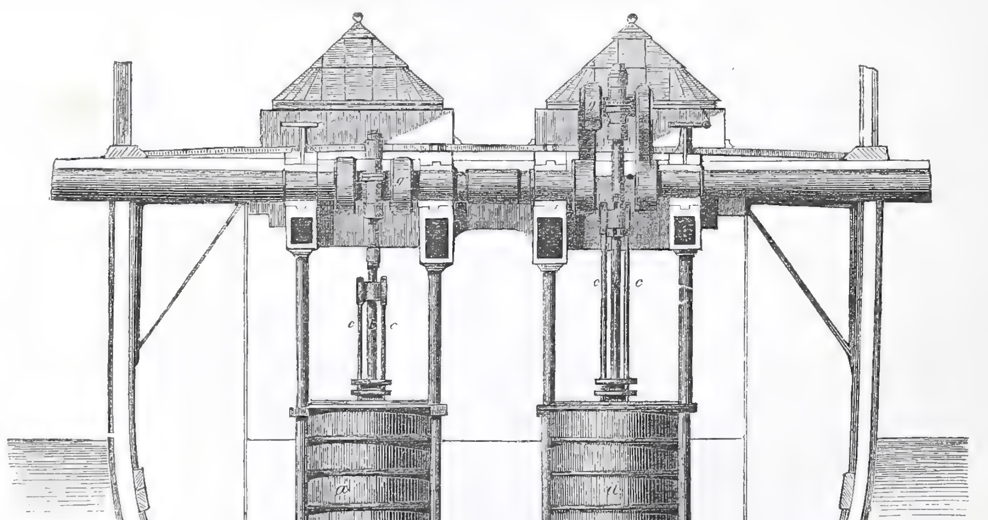
reference to the accompanying engraving, and the following description thereof, in which fig. 1 is an elevation of the said engine, taken longitudinally, fig. 2 is a horizontal plan, and fig. 3 a transverse vertical elevation, representing two such engines disposed side by side for combined action; similar letters referring to the same parts in all the figures.

The two connected working cylinders are shown at *a a*, their piston-rods at *b b*, the upper ends of which rods are affixed by keys to the cross-head, *c c c*, at the lower end of which cross-head there is a slider, *d*, working between guide ribs, *e e*, fixed



on the outer surfaces of the cylinders ; to this slider, *d*, one end of a connecting-rod, *f*, is attached, the other end of that rod being attached to the crank, *g*, of the propelling shaft.

From this arrangement it will be perceived, that by the simultaneous ascent and descent of the two pistons in their working cylinders, *a a*, the rods, *b b*, will cause the cross-head, *c c c*, to



move perpendicularly up and down between its guide bars, *e e*, and in so doing to raise and depress the slider, *d*, with the connecting-rod, *f*, which rod will, by that means, be made to give rotary motion to the crank, *g*, and thereby cause the paddle-

wheel shaft to revolve. Two rods, *h h*, connected one on each side to the slider, *d*, will, at the same time, work the air-pump beams to which the rod of the air-pump, *i*, and the feed and bilge-pumps are attached.

The steam is admitted to and withdrawn from the cylinders by an arrangement of double-beat valves, common to both cylinders. The passage of communication is always open between the two cylinders, and the steam is allowed to pass from one cylinder to the other, for the purpose of keeping the pressure equal at all times in both cylinders. The valves are worked by means of cams fixed on vertical shafts, which are driven by bevil and spur gear from a wheel on the central crank shaft. The hand gear is so arranged that one man can easily stop and start the engines.

The advantages proposed by this arrangement are, simplicity of construction, more direct action on the crank, saving of space and weight of material, and the greatest length of stroke and connecting-rod in a given height, without any lateral pressure on the pistons or piston-rods.

Fifty-six vessels have been fitted with engines on this principle, of an aggregate power of 19,130 horses.

THE MACHINERY OF THE COTTON MANUFACTURE.

CHAPTER II.

PRESSING, CARDING, CLEANING, AND SCUTCHING MACHINES.

About twelve pounds of American cotton is compressed into the space of one cubic foot, while as much as thirty to forty-five pounds of Surat can be put into the same space. Any one who has seen the above weight of cotton in its loose state, could scarcely think it possible that it could be compressed into so small a space. The latter amount of compression, forty-five pounds to the cubic foot, is effected by Laird's "Patent Colaba Press."

This form of "press" is arranged to be worked either by manual labour, or the power of cattle or steam. By the aid of twelve capstan bars, twelve men will, on the average, press from six to eight bales per hour, each weighing net 392 pounds. This quantity measures, when the final pressure is put on, 4 feet 2 inches by 1 foot 5 inches, by 1 foot 6 inches, forming a bale which measures only $8\frac{3}{4}$ cubic feet. An important feature of this press, the pressure of which is obtained by a judicious arrangement of levers, is, that it is self-contained, and requires no extraneous support. The mechanical arrangement is such, that, on motion being communicated to the capstan, the bale is pressed, the doors opened at the proper time for lashing the raw cotton passed up from the ground to the first floor, preparatory to being put into the weighing scale. In this way all strain to the machinery is prevented. By a simple arrangement, the act of turning the bale out when lashed up releases the quadrant, and the plunger rises to the top of the case, and leaves it ready to receive a fresh charge of cotton. As soon as this is put in, the shutting of the door through which it is passed to the interior of the case, releases the capstan stopper, and the capstan is at liberty to be worked. Compared with "screw-presses," the labour saved by the use of the Colaba press is two-thirds, and the time one-half. The best screw-presses take forty-one men to turn out three bales per hour of the same weight as those turned out by the Colaba press. The bales, moreover, of the screw-press, are rugged and uneven in their outline, while those of the Colaba press are perfectly square. This is no inconsiderable advantage, when we take into consideration the costliness of freight. Hydraulic presses are sometimes used to compress cotton into bales. We have seen them used for this purpose in New York. But Mr. Laird considers them too slow in their operation, and too complicated to be used abroad with advantage.

We have already noticed the invention of the "Cotton Gin" of Eli Whitney. From the important part it has played in the history of the cotton trade, our readers will probably be gratified

Fig. 6.

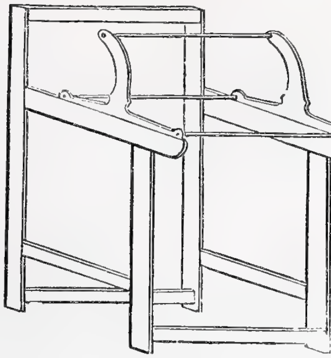
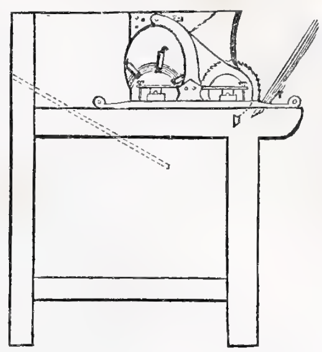


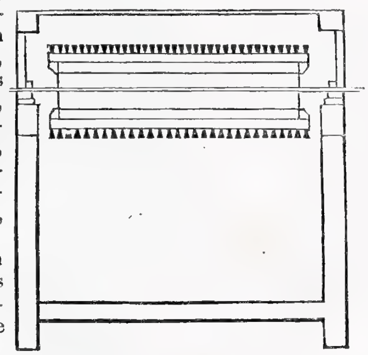
Fig. 7.



by further illustrations and descriptions of this important machine.

The cotton gin received several improvements from the inventor up to the year 1805. In 1806 and 1807, Mr. Whitney manufactured at Newhaven, Conn., seventy or eighty machines for a contract with the state of South Carolina. In this contract he was assisted by a Mr. Joseph Smith, still living at Newhaven. The gin, of which we now give drawings, is one of the machines made for this contract, and is now in the possession of Messrs. Bates, Hyde, & Co., manufacturers of the Eagle cotton gin at Bridgewater, Massachusetts.

Fig. 8.



In fig. 6, the iron brackets or curved arms for hanging the saw-cylinder and brush are shown; they are supported in the iron frame shown. Fig. 7 is an end view of the machine, showing the mode of supporting the journals. The seed board of the hopper, A, is connected with the upper part by hinges, so that it can be placed at any required distance

Fig. 9.

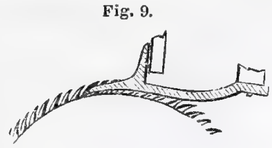
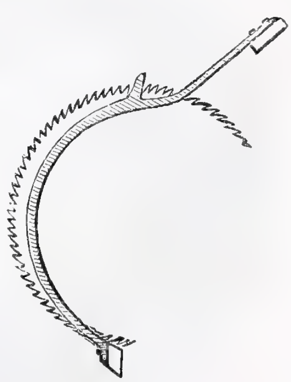


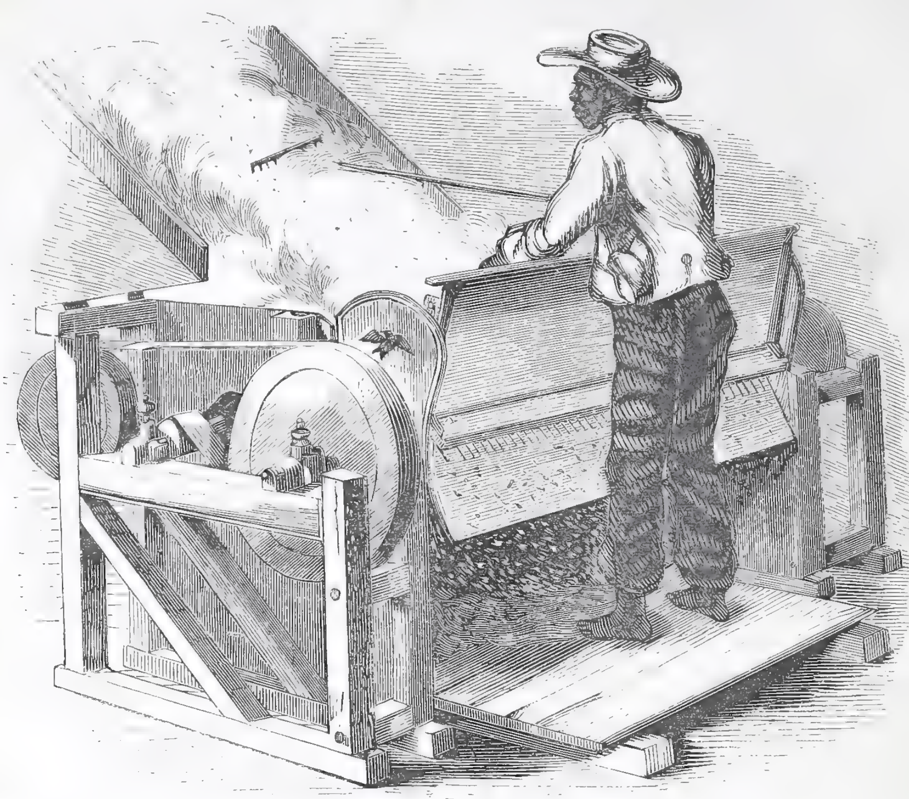
Fig. 10.



from the saw. The back, B, of the hopper descends nearly to the saws, just behind the grating. The back part of the grating makes the bottom of the moting trough, C. It also contains a moveable false bottom, made of tin, which catches the motes. There are forty saws in the cylinder, each $6\frac{3}{4}$ inches in diameter, and furnished with 106 teeth. They are kept at distances apart by block-tin or pewter rings three-quarters of an inch thick. The brush which takes off the cotton, &c. from the saws, is 7 inches in diameter, and is provided with six wings, each extending from one inch below, to two inches above the surface, where they receive oblique tufts of bristles. A longitudinal section of the brush is shown in fig. 8. The wings, as shown, extend beyond

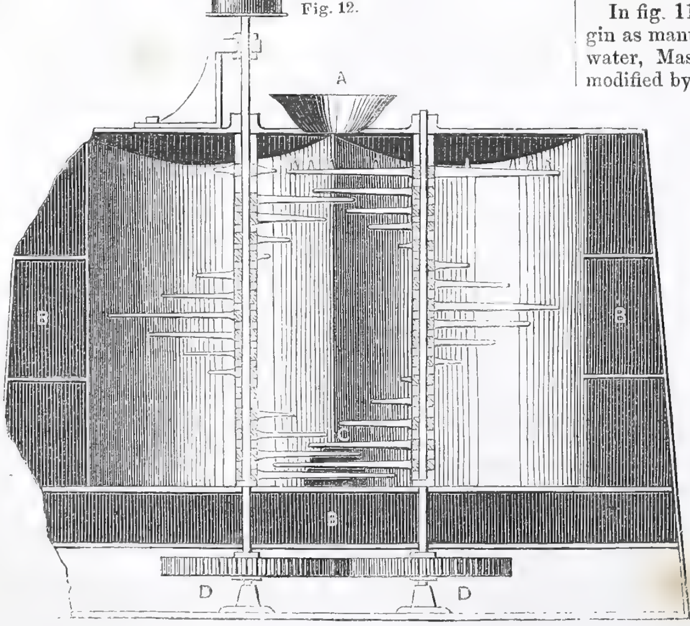
the heads, and are termed "projecting lugs." The machine has a large opening close to the ends of the brush, to admit the air freely. The projecting lugs, acting like fans, prevent the cotton from winding round the shaft of the brush, from the

Fig. 11



current of air produced. The mote-board is made of slats, two or three inches wide, and is shown by the dotted lines in fig. 7.

Fig. 12.



The hopper, moting-trough, &c., form one part of the gin, and the top and ceiling back of the openings are each hung upon the upper bar of the iron form, and may be turned back at pleasure.

In the first gin, rows of pointed wires were used, from which the transition to circular saws was natural. The cast brass grating model is shown in fig. 9. The improved grate is shown in fig. 10.

In fig. 11 we give a perspective sketch of the Eagle cotton gin as manufactured by Messrs. Bates, Hyde, & Co. of Bridgewater, Massachusetts, United States of America. Although modified by various improvements in detail and workmanship, the machine is substantially the same as that introduced and improved upon by Whitney, and of which we have now presented drawings.

We have already given drawings of Hardacre's "Cotton Opener;" we now present a sketch of his "Double-action Willow" for India. A, fig. 12, is the hopper through which the cotton is supplied to the action of the intersecting arms or batters on the vertical shafts, which revolve in contrary directions. D D, the spur-wheels giving motion to the vertical shafts, encased in the enclosure between the floor and the close bottom of the horizontal receptacle. B B are the receptacles for the expelled impurities; C is the short or open passage through which the cotton is driven or drawn out.

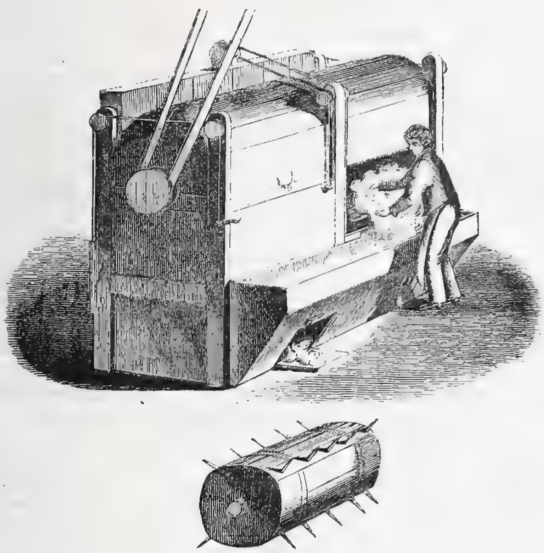
The machine generally used in our manufactories for cleaning cotton is termed the "willow," or "devil," generally the former. The operation in a "mill" is what is called the first "mixing."—See fig. 13. By the operation of mixing, different varieties and qualities of cotton are mixed together, so as to form a substitute for almost any particular quality required. Formerly, the practice was to use cotton of a certain kind and quality for a particular species of manufacture. This, however, is rarely done now, except in the case of "high counts," any desired mixture being easily obtained by the above process.

On this subject, the writer in the 'Artisan' says—" In a cotton manufacturing district, it is no rare thing to hear the complaints of the operatives as to the 'mixing' department of certain mills,

Fig. 13.

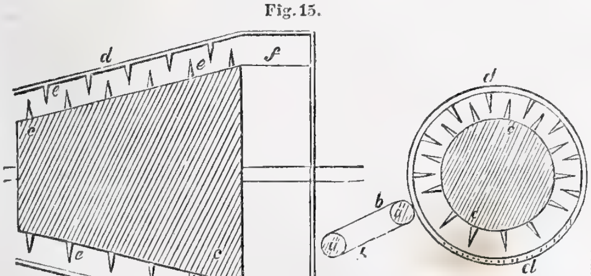
in which reference is made to the credit of the manufacturer, in preparing a mixture which is more remarkable for its ingenious composition of 'poor stuffs,' than for its capability of being easily worked up by the machines into good materials."

Fig. 14.



In the old-fashioned "willow," an illustration of which we give in fig. 14, the cotton is put into the interior of a framework, and is immediately taken up by the spikes of a revolving

Fig. 15.



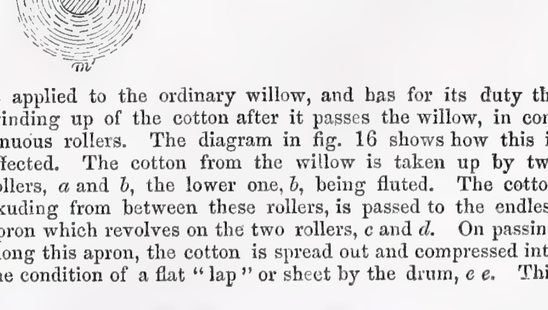
roller, and others projecting from the interior of the case in which the roller revolves. The cotton is thus disentangled, and, whilst the heavy impurities fall to the bottom, the cotton is projected in a cleaned state, the dust and lighter impurities being carried away by the action of a revolving fan.

We give, in fig. 15, a diagram illustrative of the arrangements of the improved willow, known as the "conical," introduced by the celebrated mechanician of Manchester, Joseph Lilly. The conical drum, *c c*, revolves rapidly on a horizontal axis, within a case, *d d f f*. The surface or periphery of the cone is furnished with a set of projecting teeth or spikes, the upper side of the inner case being furnished in a similar manner, the teeth of the cone moving in the alternate spaces between the teeth of the case. The machine is fed at the smaller diameter of the cone by means of an endless apron, *b b*, passing round two rollers, *a a*. This apron is made of thin spars of wood, about three quarters of an inch broad. It thus forms a flexible material, which passes easily over the rollers. The cotton fed to this apron by hand, is slowly introduced to the small end of the revolving cone. It is immediately seized by the projecting teeth, and whirled rapidly round. As the cotton passes along the surface of the cone, its speed is increased in proportion to the increase of diameter. It is finally delivered at the larger end at *f f*, and, passing on to a moving apron, is delivered disentangled. The fibres being torn open by the action of the spikes, the impurities are set free, and fall down through the grating which forms the lower portion of the outer case. The lighter dust is carried off to ventiducts communicating with the external air, a sufficient current being established for this purpose by the rapid revolutions of the cone itself.

We have already noticed the cotton opener of Hardacre, which in many factories is fast superseding the ordinary willow. The modification, of which we have given a diagram in fig. 12, is already extensively used in America for this purpose. It is thus characterized by a practical authority:—"It is found equally effective both as an opener and as a purifier, and, to use the significant expression of a practical mechanic, it is more like a mowing machine than a devil. The young persons employed have the appearance of travellers when covered with slightly driven snow. A handful of the solid matted cotton becomes an armful; and an armful a roomful, being almost instantaneously converted into a shower of beautifully opened, whitened, and purified cotton, white as driven snow when compared with its previous speckled appearance.

In the ordinary routine of operations in a mill, the cotton, after being passed through the willow, is taken to the "scutcher" or "blower," as it is usually termed in Lancashire. The cotton is passed from the willow in a loose state, and taken in baskets to the scutcher. A great improvement over this rather clumsy method is proposed to be effected by the patent feed of Messrs. Mason and Collier, of Rochdale and Halifax. The contrivance

Fig. 16.

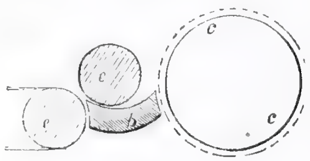


is applied to the ordinary willow, and has for its duty the winding up of the cotton after it passes the willow, in continuous rollers. The diagram in fig. 16 shows how this is effected. The cotton from the willow is taken up by two rollers, *a* and *b*, the lower one, *b*, being fluted. The cotton exuding from between these rollers, is passed to the endless apron which revolves on the two rollers, *c* and *d*. On passing along this apron, the cotton is spread out and compressed into the condition of a flat "lap" or sheet by the drum, *e e*. This

lap passes between the roller, *g*, and apron, to a second apron on the rollers, *h*, *h*. The cotton is delivered or wound round the lap roller, *n*, by the following arrangement. Beneath the roller, *h*, a second roller, *m*, revolves. Round this roller is wrapped a long continuous cloth, shown by the dotted lines. This cloth is passed under the endless apron, *h h*, over the roller, above and along the apron, and finally wound round the lap roller, *n n*. On the machinery commencing its operations, the lap roller, *n n*, is empty, and the cloth roller, *m m*, filled by the cloth round its surface. As the "wool" (so the cotton is termed in factory parlance) passes from the willow, and is delivered to the second apron, *h h*, the lap formed by the cage or drum, *e e*, is wound round the roller, *n n*, *between* the successive encirclings of the cloth, which is unwound from the roller, *m*, as fast as it is taken up by *n n*. In ordinary cases, the drum, *e e*, is made hollow, and the outer periphery of wire gauze or other perforated metal. A partial vacuum is maintained in the interior of the drum by means of an exhausting fan. By this arrangement, all loose dust, &c., remaining in the cotton is taken from it while passing over the first endless apron, *c d*.

While in this department, it may be well to notice an invention of Messrs. Mason and Collier, applicable to machines for separating seeds from cotton. The revolving saw is at *c*, fig. 17. *e*, a roller, revolving nearly in contact with the concave plate, *b*. The cotton passes between these, and as it assumes the curved form of the plate, *b*, it is kept closer up to the action of the revolving saw than is the case in ordinary machines.

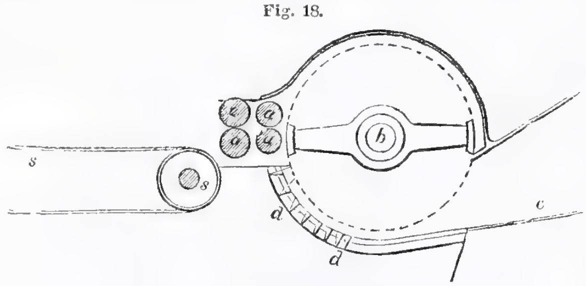
Fig. 17.



The duty which the next machine—the scutcher or "blower"—has to perform, is the still further cleansing of the cotton from all extraneous matter, and the preparing it to be made into a continuous web or sheet, to be ready for the operation of the "carding engine."

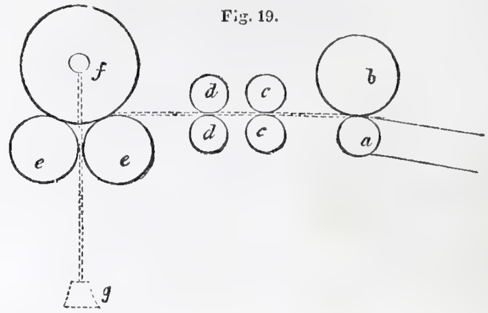
The principle of the blower will be made evident by the following diagram. The revolving beater or scutcher, *b*, fig. 18, is supplied with the cotton from the rollers, *a*, *a*. The beater, *b*, revolves at the rate of from 1,800 to 2,000 revolutions per minute. The cotton, as it exudes from between the rollers, *a a*,

Fig. 18.



is struck violently by the revolving beater. The dirt and dust pass through the grating, *d d*, a revolving fan beneath this taking it off to the atmosphere as fast as it is created. In some blowers, the cotton after passing the action of the beater is delivered to the floor in a loose state. It is then scutched a second time in what is termed a "lap machine," but is wrapped round a roller. In the plate of the "Double Beater Lap Machine" (section), we show the arrangement of a blower and lap machine in use. This is the manufacture of Mr. John Mason of Rochdale, a celebrated cotton-machine maker, to whose kindness we are indebted for drawings of various cotton machines. Previous to describing this, we shall first explain the arrangement and action of the ordinary blower and lap machines. The cotton from the willow is opened by hand on an endless apron, which delivers it to the delivering or feed rollers. On passing from between these, it is struck by the first beater. After passing this, it is wafted up an inclined plane or apron to a second pair of feed rollers, in passing from which it is struck by a second beater, which revolves more quickly than the first beater. The cotton is next passed to an endless apron, and beneath a revolving cage or drum, a similar drum having operated on the cotton in passing over the first endless apron. Passing from the second apron, it is finally delivered through a pair of rollers, and lastly wound round a lap roller. The lap, as it passes to the roller, is

Fig. 19.



consolidated by an arrangement, of which fig. 19 is an explanatory diagram. The cotton, after passing from the second beater, travels up the second inclined endless apron to the rollers, *a*, *b*. Passing between these, it is delivered to the two pair of rollers, *c c*, *d d*, the upper one of each pair being loaded by hanging weights attached to their axles. The two rollers, *e*, *e*, revolving in the same direction, cause by their friction the lap roller, *f*, to revolve also. The axis of this is loaded by a link and weight, *g*. The cotton is passed from the last pair of rollers, *d d*, to *f*, round which it is wound in a continuous sheet. As each revolution, by taking in a determinate quantity of cotton, will cause the diameter of *f* to increase, it rises in its bearings (which are made to allow of this movement), taking with it the link and weight, *g*. As soon as the attendant notices that a sufficient quantity of lap is taken up by the roller, *e*, the beaters and rollers, *c*, *c*, are thrown out of gear, and cease revolving. The rollers, *d*, *d*, however, are not thrown out of gear, and continue to revolve. The consequence is, that the lap of cotton is torn across between the rollers, *d d*, *c c*.

In the condition of a lap wound round a roller, we suppose the cotton to be taken to the double beater lap machine, of which in in one plate we give a section, and in another an elevation. In the section, the rollers from the lap machine are marked 1 1, 2 2, 3 3. As the lap is taken from these, the rollers descend in the slotted bearings in which they revolve. The lap from each roller is taken by an endless apron, and delivered to the feed rollers of the beater. It will be evident that, by the arrangement of lap rollers, any desired quality of cotton may be passed from the machine, by supplying each roller with a different quality of cotton. The lap, as before mentioned, always rests on the endless apron revolving on the rollers, *s*, *s*, by which the cotton is carried forwards to the feed rollers, *a*, *a*. In passing from between these, it is struck by the beater bars, *b*, the heavy impurities passing through the circular grating shown in the drawing. The cotton then passes up the inclined plane, *c*, likewise grated, between the perforated cages, *d*, *d*. The interior of these is partially vacuous, by means of the revolving fanners, *e e*. The cotton next passes between the intermediate rollers, where it is formed into a species of lap. This is next passed to the rollers, *f*, and on passing from these it is subjected to the action of the second beater. Passing up the incline, *g*, between the cages, *h*, *h*, it is finally delivered to the lap roller revolving in the slotted bearing, *p*. The cotton passes through the arrangement of rollers shown in the section, and known as "Mason's Patent Condenser." This arrangement causes a very great quantity of cotton to be wound round the lap roller.

We now proceed to notice a few of the patented improvements in this department of cotton mechanism. The first we give is that of Messrs. Fairbairn and Hetherington, of Leeds and Manchester. The improvement proposed to be effected by this arrangement, is the distributing the opened fibres in a more uniform condition, previous to being lapped, than is effected by

machines of the ordinary construction. After passing from the beater, the cotton is taken up by a perforated cylinder, *a*, fig. 20, the interior of which is partially exhausted. This causes the cotton to adhere, in some measure, to the periphery of the cage. The outer case, *b b b*, is so shaped that it causes the cotton to be laid more uniformly on the lap roller. The same patentees have a method of lapping a large quantity of cotton round the lap roller. The lap roller, *c*, is placed horizontally (fig. 21) before the rollers, *a*, *a*, in place of being under, as in the usual form. The upper roller revolves in contact with, and is supported by the intermediate roller, *b*. The cotton passes between the lap roller, *a* (the under roller in the diagram), and this intermediate roller, *b*. By this arrangement, the lap is less distended than when passed round the lap roller placed above, as in fig. 19. In the arrangement in fig. 19, as the lap roller, *f*, increases in diameter, it rises up in its bearings, taking with it the link and weights, *g*. By this means the pressure is always uniform. In the arrangement of Messrs. Hetherington and Fairbairn, in fig. 21, the pressure is kept uniform by the following mechanism. The roller, *c*, is supported in bearings on a traversing frame, so that it is capable of moving out and in, as shown in the diagram by the arrow, *d*. By means of hanging weights, the traversing frame is kept so that the roller, *c*, presses uniformly on the rollers, *a*, *a*, the frame giving way and moving from the rollers, *a*, *a*, as shown by the arrow, *d*. As one roller, *c*, increases in diameter, motion is given to the roller, *c*, entirely by means of the friction of the rollers, *a*, *a*.

Fig. 20.

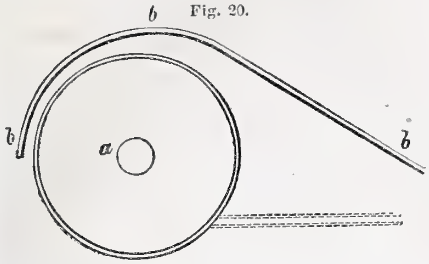
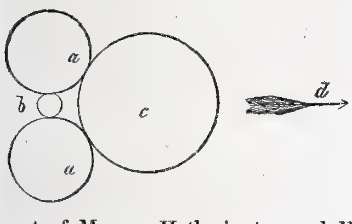
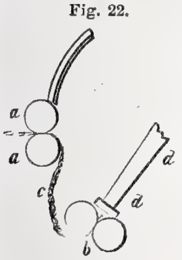


Fig. 21.



Another improvement in blowers or scutching machines we may here notice, is that of Messrs. Tatham and Cheetham of Rochdale. It consists in the application of a second pair of rollers in the position at *b*, fig. 22. The cotton, as it passes from the ordinary feed-rollers, *a*, *a*, is struck by the scutcher, *d*. But in place of passing at once to the grating, it is made to go to the second pair of rollers at *b*, on exuding from between which, it is again struck by the scutcher. By this arrangement, the cotton is subjected *twice* to the action of the scutcher during one revolution.

Fig. 22.



In the following chapter we will proceed to describe the working and mechanism of the "carding-engine."

INORGANIC CHEMISTRY.

CHAPTER V.

GENERAL COURSE OF QUALITATIVE ANALYSIS.

PRELIMINARY OPERATIONS.

The quantity of matter operated upon should never be large (from 30 to 50 grains), and a small portion should always be reserved in case of accidents. The first step is generally to ascertain the presence or absence of organic matter. For this purpose a very small portion is heated in a small test-tube over the gas flame, holding the tube in a slanting position. If organic matter be present, the substance will almost in all cases be charred, and there will be a development of empyreumatic oil and of water. A piece of red litmus paper inserted within the tube, at a sufficient distance from the heated part, will turn *blue* from the ammoniacal fumes, if nitrogen be present. If no organic matter be present, the above experiment will detect the existence of water, of ammoniacal salts, and various other volatile bodies. As organic matter interferes seriously with the action of many reagents, it must be destroyed before the final analysis is undertaken. This is best performed by carefully igniting the substance in a porcelain crucible with pure saltpetre, or with peroxide of barium. The degree of heat should be judiciously regulated, and the substance introduced by small portions at a time. After thus ascertaining the presence or absence of organic matter, the sample may be submitted to a variety of blowpipe experiments, which in many cases will enable the analyst to pronounce at once upon its nature, and in others will give valuable indications for completing the process. Of these operations we shall treat in the next chapter.

The solubility of the body is now to be ascertained. A portion reduced to fine powder is mixed with an excess of water, and, if necessary, heated to the boiling point. If the substance is but partially soluble, the clear liquid is filtered off and set aside, whilst the insoluble residue is treated with various acids. To determine, in doubtful cases, whether water has taken up any part of the substance, a drop of the filtered liquid is evaporated to dryness on a piece of platinum foil. If anything has been dissolved, a stain remains behind. The residue insoluble in water, or the whole mass if unaffected by that solvent, is now successively treated with hydrochloric acid, nitric acid, and aqua regia, the clear liquid being each time removed from the insoluble residue (if any) by filtration or decantation. During the action of these acids, many bodies are decomposed, and their nature is indicated by the gases that escape, or by other phenomena. If a part, or the whole of the substance resist the action of acids, it is ground to fine powder, mixed with carbonate of soda or potash in excess, and ignited in a platinum crucible. If this prove inefficient, caustic potash is applied in a crucible of silver or pure gold. According to the most recent researches, lime is preferable to either caustic or carbonated alkalies for rendering the silicates soluble. Metals are generally best dissolved in nitric acid, or, if that prove inefficient, in aqua regia.

Case I.—Analysis of compounds soluble in water, containing only a single base and acid (or metal and non-metallic element), included in the following list:—Potash, soda, ammonia, baryta, strontia, lime, magnesia, alumina, chromic oxide, manganese (protoxide), zinc oxide, cobaltic oxide, nickel oxide, ferrous oxide, ferric oxide, cadmic oxide, lead oxide, bismuth oxide, cupric oxide, silver oxide, mercurous and mercuric oxides, gold oxide (proto and per-oxide of), antimonic oxide. Sulphuric, nitric, phosphoric, arsenic, boracic, carbonic, arsenious, sulphurous, silicic, iodic acids; chlorine, iodine, fluorine, sulphur.

(A.) The substance is soluble in water.

And 1.—*Detection of the Base.*

Acidulate a part of the aqueous solution with muriatic acid. If a white precipitate appear, the base is either oxide of *silver*, *mercurous* oxide, or oxide of *lead*. If ammonia redissolves a part of the precipitate, it is *silver;* if a black colour is produced, *mercurous oxide;* if no action ensues, oxide of *lead.* Apply further tests for confirmation, as given above.

If no precipitate appears, pass H.S. through the liquid. If a precipitate then falls, it indicates a sulphuret of one of the following metals:—Cadmium, lead, bismuth, copper, silver, mercury (both sulphurets), gold, tin (both sulphurets), antimony, and arsenic, if arsenic or arsenious acid was present. Sulphur may likewise be precipitated, if a persalt of iron exist in the solution.

The precipitate is black, or deep brown.—Lead oxide, oxide of bismuth (rarely present except in acid solutions), cupric oxide, oxide of gold, protoxide of tin, mercuric oxide (mercurous

oxide and oxide of silver are excluded by the previous addition of muriatic acid). Apply the special tests given above.

Sulphuret orange.—Oxide of antimony.

Sulphuret yellow or white.—Oxide of cadmium, peroxide of tin (arsenious and arsenic acids), and peroxide of iron. In the last case the precipitate is only sulphur. Test the original solution.

If S.H. gives no precipitate, add ammonia, and then hydrosulphate of ammonia.

Precipitate black.—Nickel, cobalt, protoxide of iron. Test the original solution.

Precipitate dull green.—Chrome. Test original solution. Use blowpipe.

Precipitate flesh-coloured.—Manganese. Test original solution. Blowpipe.

Precipitate white.—Alumina, oxide of zinc. Test original liquid.

If neither H.S. nor hydrosulphate of ammonia give a precipitate, take a part of the original solution, and add carbonate of soda. If a precipitate appear, the base is magnesia, baryta, strontia, or lime. Test original solution as directed.

If no precipitate appear, the base must be either potash, ammonia, or soda. Test original solution, and use blowpipe for soda.

2.—*Detection of the Acid.*

A knowledge of the base of a soluble salt throws considerable light upon the nature of the acid, those only which are capable of forming soluble salts with the ascertained base requiring to be taken into consideration.

To a portion of the solid salt add dilute sulphuric acid; if effervescence arise, the acid is either sulphurous, carbonic, or hydrosulphuric (formed by the action of a dilute acid upon a metallic sulphuret). Test these by their odour; the two latter also with lime-water and salts of lead. If the body take a brown tinge, hydriodic acid (iodine) is present. Test as above.

If neither effervescence nor a brown colour appear, concentrate and neutralize a portion of the original solution. Acid solutions may be neutralized with ammonia, those which are alkaline with nitric acid. Then add chloride of barium. If a precipitate falls, it indicates sulphuric, phosphoric, arsenic, iodic, boracic, silicic, or hydrofluoric acids. Test for these as above, using also the blowpipe for silicic, and observing the reaction with glass for hydrofluoric.

If chloride of barium yield no precipitate, add nitrate of silver to the original solution, which must be neutral, or mixed with nitric acid. If a precipitate appear, the acid is hydrochloric or hydriodic. Test as above. If no precipitate fall, the acid must be either chloric or nitric. Test the dry substance.

(B.) Substances similar in constitution to the preceding, but insoluble in water.

1.—*Detection of the Base.*

Effect a solution as already directed, and add a large excess of water to a part of the acid solution. If the liquid becomes turbid, antimonic or bismuthic oxide is probably present. If the former, the liquid is rendered clear again by the addition of tartaric acid; if the latter, by that of acetic. The absence of turbidity is, however, no conclusive proof of the absence of these two bases.

Pass sulphuretted hydrogen through the solution; a *black* precipitate then indicates oxide of lead, bismuth, gold, protoxide of copper, tin, and mercury, suboxide of mercury, or oxide of silver.

An *orange red* precipitate shows antimonic oxide.

A *yellow* or *white* precipitate shows cadmic oxide, peroxide of iron or tin, an acid of arsenic. If the precipitate is fusible, volatile, inflammable, and insoluble in ammonia, it is merely sulphur, and shows the presence of certain acids, such as the nitric, iodic, bromic, chromic, sulphurous, and nascent chlorine.

If S.H. precipitate nothing, or only sulphur, add excess of ammonia, and afterwards hydrosulphate of ammonia, to a part of the acid solution.

Precipitate black.—Oxide of nickel, cobalt, protoxide of iron.

Precipitate green.—Chromic oxide.

Precipitate flesh-coloured.—Manganese.

Precipitate white.—Alumina, oxide of zinc, magnesia, lime, strontia, baryta (in certain combinations), and silicic acid. Test for the latter; if present, evaporate the solution to dryness, redissolve in dilute acid, filter and test the clear liquid for the remaining substances. If no precipitate appears, add carbonate of potash in excess to a portion of the original solution, and apply heat. If a precipitate appear, it is either magnesia, lime, strontia, or baryta. Test the original liquid.

Except silicic acid is present to a considerable extent, there is no occasion to search for alkalies.

2.—*Detection of the Acid.*

Effervescence, on treating the dry substance with hydrochloric acid, shows either carbonic, sulphurous, or hydrosulphuric acid, the latter from a metallic sulphuret. If the substance is insoluble in hydrochloric acid, pulverize and boil a part in nitric acid. If red fumes are given off, and a yellow clotty powder separates, we suspect a sulphuret. Chloride of barium then gives a white precipitate in the acid liquid, insoluble in excess of water.

If this reaction do not appear, heat another portion with strong sulphuric acid. Purple vapours of iodine show an iodide; caustic fumes, capable of corroding glass, a fluoride; a green flame on adding alcohol and igniting, a borate.

If none of these results be produced, evaporate a part of the acid solution to dryness, and digest the residue in boiling hydrochloric acid. An insoluble residue is probably silicic acid, which examine. Then add chloride of barium to the hydrochloric solution. A white precipitate shows sulphuric acid.

If the base is one of the oxides precipitated by sulphuretted hydrogen, remove it by means of a current of that gas; filter, boil the clear liquid to expel sulphuretted hydrogen, and add molybdate of ammonia. A yellow precipitate indicates phosphoric acid. If the base is one of the oxides, precipitate only by hydrosulphate of ammonia or an alkaline earth, perchloride of iron in excess is added to the hydrochloric solution, and then a slight excess of ammonia. The precipitate is treated with acetic acid, the insoluble portion thrown on a filter, washed, and digested in hydrosulphate of ammonia. The whole is then filtered, and the clear liquid tested for phosphoric acid as usual. If the base is alumina, the substance should be dissolved in as little nitric acid as possible, nitrate of silver added, and then ammonia enough to saturate the free acid, when the yellow phosphate of silver oxide becomes apparent.

If no phosphoric acid should be found, add nitrate of silver to a solution of the substance in nitric acid. A white precipitate shows chlorine. Verify by the usual tests.

Chloric acid forms no insoluble salts, and consequently need not be sought. If a portion of the substance deflagrate on burning charcoal, nitric or iodic acid may be present. Test as above directed. Arsenic and arsenious acid are precipitated by sulphuretted hydrogen, and must be sought for accordingly.

(C.) Substances similar in composition to the preceding, but insoluble both in water and acids.

These substances are few in number; we find amongst them certain sulphates, silicates, and chlorides, and a few metallic oxides in the insoluble modification.

The mass, finely pulverized, is ignited with an excess of carbonate of soda in a platinum crucible for about half-an-hour. When cold it is pulverized, digested in hot water, and filtered.

The clear liquid contains the soda in combination with the acid of the insoluble substance. Test for chromic acid, silica, sulphuric acid, arsenic acid, chlorine, and peroxide of tin.

The residue insoluble in water must be examined for metallic silver and chromic oxide. If neither is present, it is dissolved in an acid, and systematically examined as above prescribed.

If carbonate of soda produce no effect, the substance is next treated with caustic alkali, or preferably with lime, and examined in precisely the same manner.

(D.) Complex bodies containing some of the same constituents; soluble in water.

In the examination of complex bodies, if any reagent produce a precipitate, it must be added in sufficient quantity to

precipitate *the whole* of the base or acid in question, in order that it may be removed from the solution.

Dissolve in water, and add hydrochloric acid. If a precipitate is formed, continue adding until the whole has fallen, and then filter.

If there is no odour of S.H. on adding hydrochloric acid, the precipitate may be chloride of lead, silver, and mercurous chloride. Preserve the clear liquid and wash the filter. *Chloride of lead* may be entirely dissolved away in this manner, and detected in the washings. Then wash with ammonia, which will dissolve *chloride of silver*, if present. Test the solution. *Mercurous chloride* will remain, blackened upon the filter.

If S.H. is manifested on the addition of muriatic acid, the precipitate may contain *sulphur*, and the sulphurets of *tin, antimony, arsenic*, and *gold.* To ascertain the presence of *arsenic*, a portion of the precipitate is carefully dried, and intimately mingled with from 10 to 12 times its weight of a mixture of three parts carbonate of potash (dry), and one part cyanide of potassium. The mixture is placed in a small test-tube, and heated to redness over the gas flame. Metallic arsenic sublimes if present, and condenses on the side of the tube, forming a spot like a mirror. The method of distinguishing the other three metals will be given below. The liquid, after saturation with hydrochloric acid, may be now examined for *alumina* and *chromic oxide.*

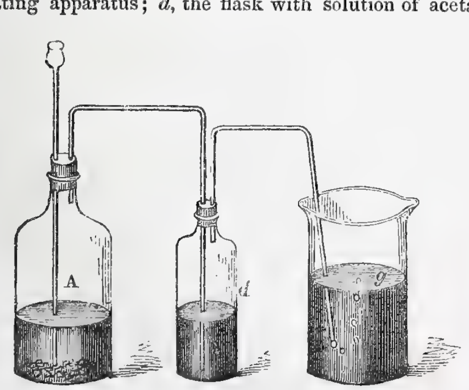
The precipitate produced by hydrochloric acid, if any, being removed by filtration, a current of H.S. is passed through the liquid for some time. If a precipitate is formed, it is separated from the liquid by filtration.

If the precipitate formed is clear yellow, it is examined for *arsenic* as above. If that metal is present, no other bases save the *alkalies* are likely to occur. Evaporate the filtered solution to dryness, and test as above.

Or a yellow precipitate may consist partially or wholly of sulphur. Examine as above.

If the precipitate be of any other colour than yellow, or do not consist entirely of arsenic or of sulphur, it is digested in warm hydrosulphate of ammonia. Should, however, copper be present (which may be ascertained by dissolving a small portion of the precipitate in ammonia), sulphuret of potassium or sodium is to be employed. If the whole does not dissolve, filter.

a. The *solution* is acidulated with hydrochloric acid, and reprecipitated with sulphuretted hydrogen. This precipitate, which may contain sulphurets of tin, arsenic, antimony, and gold, is redissolved in aqua regia, and the solution put in an ordinary apparatus for generating hydrogen gas, so arranged as to allow of washing the gas with a dilute solution of acetate of lead, which absorbs any muriatic or sulphuretted hydrogen gas, and to pass the mixture of antimoniuretted and arseniuretted and free hydrogen into a test-tube half-full of pure strong nitric acid; see fig., where A represents the gas-generating apparatus; *d*, the flask with solution of acetate of



lead; and *g*, the test-tube with nitric acid. If the gas is passed moderately slowly, the whole of the metallic hydrides (arseniuretted and antimoniuretted hydrogen) are decomposed, forming water, arsenic, and antimonic acid. After passing the gases for about half-an-hour, the nitric acid solution is evaporated to dryness; the residue heated upon the sand-bath, in order to expel the last traces of nitrc acid, containing arsenious, arsenic, and antimonic acid.

The residue is now exhausted with warm water, which takes up all the arsenic and arsenious acid. The aqueous solution, mixed with nitrate of silver, and neutralized, drop by drop, with ammonia, yields, if arsenic be present, a precipitate of arsenite or arseniate of silver. The residue left, after complete exhaustion with water, is antimonic acid. It is dissolved in the smallest possible quantity of aqua regia (if the quantity be very minute, filter and all being boiled); the excess of acid is evaporated as far as possible, and the remaining solution mixed with sulphuretted hydrogen. If a trace of antimony be present, the liquid at once assumes an orange-yellow colour, and, on boiling, orange flakes are separated. The detection of tin presents no difficulty. The whole of this metal remains behind in the flask, *a*, either as protochloride, or as a finely-divided metallic precipitate. If the quantity of tin is considerable, it is sufficient to filter the liquid in the apparatus, and add to the filtered liquid protochloride of mercury. A white precipitate of subchloride of mercury indicates the presence of tin. Should this experiment yield no results, the metallic precipitate (tin, with a portion of antimony and arsenic) is detached from the zinc plates, dissolved in hydrochloric acid, and tested with protochloride of mercury. The reagents employed should, of course, be perfectly pure. To detect gold, a portion of the original solution, *a*, is diluted with water, and acetic acid added. The precipitate produced is collected on a filter, washed, and examined, if anything beside sulphur be present. If that is the case, it is placed in a capsule, drenched with strong muriatic acid, and boiled for a quarter of an hour, adding fresh acid as required. The liquid is then diluted, and filtered. Sulphuret of gold, if present, remains undissolved, along with free sulphur. The residue is digested in aqua regia, and tested for gold in the usual manner.

b. The residue not taken up by hydrosulphate of ammonia may contain cadmium, lead, bismuth, copper, and mercury. Wash the precipitate, and digest in hot strong nitric acid; sulphur separates, and is slowly oxidized, and the sulphuric acid thus formed precipitates a portion of lead, if present. Dilute the liquid and filter.

a. a. The liquid may contain cadmium, bismuth, lead, and copper. Evaporate a part to dryness, and drench the residue with water. A white insoluble mass indicates *bismuth.* Verify with blowpipe, and test clear liquid for *lead.* To the rest of the solution, *a a*, add an excess of ammonia, and filter, if a precipitate falls. To the ammoniacal solution a small excess of hydrochloric acid is added, and then carbonate of ammonia. A white precipitate shows *cadmium*, a blue colour, *copper.*

b. b. Undissolved may remain sulphuret of mercury, sulphur, and sulphate of lead. On heating a portion in a test-tube over the gas flame, the two former sublime. Test for *lead* in the residue with hydrosulphate of ammonia. Heat another portion in a test-tube with carbonate of soda, *mercury*, if present, will sublime and condense in drops on the sides of the tube.

The clear liquid filtered off from the precipitate produced by sulphuretted hydrogen (if any) is next examined. A small portion of it is mixed with ammonia in slight excess, and hydrosulphate of ammonia is next added. If a precipitate falls, the whole of the liquid is treated in the same manner, filtered, the clear filtrate set aside, and the precipitate washed. The precipitate is then digested in dilute nitro-hydrochloric acid, the solution diluted, filtered if requisite, and ammonia added in excess to a portion. 1. If a precipitate falls, the whole of the liquid is treated in the same manner, the mixture warmed, and filtered. If little acid remains in the solution, chloride of ammonium should be previously added. The precipitate may contain *ferric oxide, chromic oxide*, and *alumina.* It is washed, dissolved in a little muriatic acid, and the liquid treated with caustic potash in excess. *Ferric oxide* is precipitated. Filter, redissolve, and test. Chromic oxide and alumina may remain in solution. The former is precipitated on prolonged boiling. The latter is sought in the residual liquor. 2. The clear filtrate

is now treated with hydrosulphate of ammonia as long as a precipitate continues to fall. It is then thrown upon a filter, washed, and dissolved in nitro-hydrochloric acid. There may occur cobalt, nickel, zinc, manganese. Mix the solution with caustic potash in excess, heat and filter if requisite.

2 *a*. The precipitate may contain cobalt, nickel, and manganese. It is washed and treated with a hot mixture of ammonia and carbonate of ammonia. This liquid will dissolve cobalt and nickel, if present. The solution is evaporated to dryness, and the blowpipe test applied for *cobalt*. The rest is redissolved in as little hydrochloric acid as possible, evaporated again, dissolved afresh in water, and cyanide of potassium added in excess. If the liquid, when mixed with dilute sulphuric acid and warmed, give, on standing, a precipitate, *nickel* is present. *Manganese*, if present, resists the solvent action of ammonia, and must be tested for with the blowpipe.

2 *b*. The clear liquid may contain *zinc*, for which apply the usual tests.

The liquid filtered off from the precipitate yielded by hydrosulphate of ammonia. Ascertain the presence of a fixed base by evaporating a few drops to dryness upon platinum foil. Boil to expel all S.H., adding muriatic acid in slight excess. Carbonate of ammonia and caustic ammonia are then added, and the whole allowed to boil for some time. If a precipitate appear, it may consist of *lime*, *strontia*, and *baryta*. Redissolve in a very little muriatic acid, and test for these earths. The residual liquor filtered from the above precipitate may still contain magnesia, potash, and soda. Dilute a portion, and add phosphate of soda; if a precipitate falls on agitation, *magnesia* is present. The remainder of the solution should now be evaporated to dryness, and ignited in a platinum crucible. Redissolve in a little water, and add baryta water, which precipitates all the magnesia. Filter and add sulphuric acid to remove any excess of baryta. Boil, filter again, and evaporate to dryness. Ignite, redissolve in water, and test for *potash* and *soda*. Ammonia may be detected by treating a portion of the original solution with caustic potash, and examining the fumes generated.

COMPENDIUM OF LOGIC.

CHAPTER I.

DEFINITION — VALUE OF LOGIC AS A STUDY — HISTORICAL OUTLINE.

Logic has been defined by some authorities as the Art of Reasoning; but this definition is undoubtedly too limited. Archbishop Whately, " a writer," says Mr. J. S. Mill, " who has done more than any other living person to restore the study to the rank from which it had fallen in the estimation of the cultivated classes of our own country, has adopted the above definition, with an amendment; he has defined logic to be the Science as well as the Art of Reasoning; meaning, by the former term, the analysis of the mental process which takes place whenever we reason; and by the latter, the rules, grounded upon that analysis, for conducting the process correctly." " There can be no doubt," adds Mr. Mill, " as to the propriety of the emendation."

The celebrated Dr. Watts attempted a further generalization, by publishing a system of logic, which he termed " *The Right Use of Reason*." The object of this publication was to supersede the scholastic logic, by laying down general rules for " invigorating and properly directing all the powers of the mind." " A most magnificent object, indeed," says Whately, " but one which not only does not fall under the province of logic, but cannot be accomplished by any *one* science or system that can even be conceived to exist." This condemnation of Dr. Watts' laudable effort, which rescued logic from a mass of verbiage, and largely contributed to bring it into higher estimation than it had previously enjoyed, ought to be received with caution; for Dr. Whately restricts logic to a train of reasoning carried on by words or signs alone, and acknowledges that his own logical treatise " professes to be wholly conversant about *language*."

On the whole, we are inclined to adopt, as marking out in all its extent the proper domain of logic, the lucid definition of Mr. Stuart Mill, that " Logic is the science of the operations of the understanding, which are subservient to the estimation of evidence; both the process itself of proceeding from known truths to unknown, and all intellectual operations auxiliary to this." " It includes, therefore," says the same writer, " the operation of Naming; for language is an instrument of thought, as well as a means of communicating our thoughts. It includes, also, Definition and Classification." This definition of logic will be rendered sufficiently complete for our purpose, by adding, that it also embraces the *art* of reasoning, founded on the science so called.

On the value of logic as a study, the most different opinions have been entertained. In the age of the Greek sophists, and in later mediæval times, when the area of human knowledge was limited, it constituted almost the sole occupation of the learned. Logic was the great study of the middle ages. When ascertained physical facts were few, and the vast volume of nature was yet a sealed book, the mind of man was thrown back upon itself, and wasted all its ingenuity in logical quibbles and speculations. To reason, whether right or wrong, became the great art, the *ars artium ;* skill in disputation was the test of philosophical eminence; philosophers travelled over Europe to dispute and wrangle, and hence we have still, in our English universities, the honour of *senior wrangler*, as the mark of highest proficiency; although it is true, that the skill in logomachy (or *wrangling*), from which the title was originally derived, has now given place to the solid and profound researches of physical and mathematical knowledge.

From the time of Bacon, the vaunted knowledge of the schools (or middle-age pseudo-philosophers) has fallen into merited disrepute. The vain attempt to elucidate all knowledge by mere reasoning, speculating, and quibbling, without taking the trouble to investigate and ascertain facts, was justly and sagaciously denounced by that comprehensive thinker—the father of modern philosophy, in all its branches. We say, the father of modern and true philosophy; for, although Bacon contributed little to the facts that constitute modern science, he pointed the way to their accumulation by his doctrine of " interrogating nature," and to that indispensable classification which crystallizes a multitude of facts into a lucid, transparent, scientific system.

Scholastic logic, having fallen from the lofty position which it had so long usurped to the exclusion of more important studies, descended into almost total neglect, or was only mentioned with contempt in the new-born schools of philosophy. As commonly happens in such cases, that which was really good in the science (for we propose to term it indifferently either an art or a science) shared the disgrace of the absurdities with which it had been loaded by the schoolmen; and not only physical experimentalists, but even the metaphysicians themselves, affected to regard its multitudinous rules and distinctions as a barbarous and exploded jargon. It is only within the last quarter of a century that logic has begun to recover a portion of its former estimation in the public mind. Among the uneducated masses, indeed, it has never ceased to be regarded with a kind of traditional reverence, as embracing in itself the essence of learning, and the art of irresistible demonstration. As such, the very word, logic—the terms, logical reasoning, a logical mind, &c., are incorporated with common language, and are often applied or attributed to persons who may be entirely unacquainted with the formal rules of the science. Indeed, it may be stated as a general rule, that few who are now in the learned professions have given it much of their attention as a special and distinct branch of study. It has never been totally neglected in the universities; but still we can state, that even in these, as far as our own experience goes, it has always, till of late, been regarded as a relic of the semi-barbarous era, when quibbling took the place of philosophy, and visionary speculation of science.

A true estimate of logic will probably be found to lie in a medium between the mysterious reverence of those who know

nothing about it, and the equally extreme contempt of those who have studied (and studied superficially) only the logic of the schools. We would warn the former to beware of the delusion, that a knowledge of the formal rules of logic, or of its numerous technical terms, is essential to correct reasoning; while, at the same time, we have no hesitation in saying, that a careful study of some of the best recent logical treatises, will be found largely conducive to accurate thinking, and therefore, as a matter of course, to valid and incontrovertible reasoning.

On this point we cannot agree with Archbishop Whately, who, in his exalted notions of the science, pronounces logic to be, " as it were, the grammar of reasoning," and says, that to condemn the syllogistic theory as unessential to argumentative skill, is " a mistake no less gross than if any one should regard grammar as a peculiar language, and should contend against its utility, on the ground that many speak correctly who never studied the principles of grammar." We hold that, to reason correctly is very different from speaking correctly. Persons who have studied neither grammar nor logic may and will, if possessed of general intelligence, reason conclusively and clearly on any subject, although, both in speaking and writing, they may violate every rule of grammar. There is really no valid ground of comparison between the two cases. Grammar is an arbitrary, mutable system; its rules may and do vary in different languages; they are, to a great extent, constructive or artificial,—whereas the fundamental rules of reasoning are established in the very nature of things; they are more or less intuitive in every mind, and so far is the formal study of logic from being an *essential* to the exercise of the reasoning power, that we would prefer the mathematics as a discipline for that exercise, if one alone could be embraced, and the choice of the student was restricted to logic or the mathematics. Geometry and algebra we hold to be higher disciplinarians for clear, consecutive, and cogent reasoning, than even logic itself, although it be pre-eminently termed the Science and Art of Reasoning. Indeed, it is impossible even to study with advantage some of the advanced works on logic, such as Mr. Stuart Mill's " System," or the writings of Sir William Hamilton, without a preliminary knowledge of the mathematics. A mathematician may not be an accomplished logician, but it is impossible that he can be imposed on by sophistry, or that he can reason inconclusively.

Still, let it not be supposed that we depreciate the importance of logic, either as a science or an art, although we can by no means subscribe to the extravagant encomiums of the schoolmen, by whom it was represented as " the divine art, the irrefragable canon, the eye of the intellect, the art of arts, the science of sciences, the organ of organs, the instrument of instruments, the servant, the key, the containing vessel, the bulwark of philosophy, the chief master in teaching and in speaking, the umpire and judge of the true and false." To this extravagant laudation, even while the science was clothed with absurdities, logic is perhaps indebted for much of its subsequent disgrace, from which it is beginning to revive in a new and more rational form. Logic may indeed be termed the " art of arts," or rather, we should say, the science of sciences, inasmuch as it investigates the principles of reasoning, and lays down rules for their application in every department of science. It accompanies, and assumes to guide, the march of the rational and inquiring mind over the entire field of knowledge. It does not relate to any particular science, or to any particular kind of reasoning, but to all reasoning, to all inference, to all research after truth, and, therefore, to all science and all doctrine. Much may be done without its formal study, without even a knowledge of its terms. Many of the most logical minds of the age have never been acquainted with its rules and teachings, reduced to a systematic form. There is an intuitive logic (though not an intuitive grammar), inherent, and constantly in exercise, in every intelligent, discerning mind, the want of which can never be compensated by studying logical treatises. The latter, however, will improve the reasoning powers, by giving distinctness to our abstract conceptions, as well as precision to our language, and by placing the mind on its guard against fallacies to which it is continually exposed from the frequent ambiguity of words, the assumption of unwarranted premises, or other sources of error.

Having thus explained what we conceive to be the true province of logic, and the nature and extent of the advantages that may be expected from its study, we think it will scarcely be disputed, that an outline of its terms, principles, and rules, may not be entirely incongruous with the object of the present work. To reason correctly, and to judge of the validity of reasoning, are essential upon all topics, and more especially in studying or discussing subjects that partake of a scientific character. Even in general treatises, terms borrowed from the technical language of the schools are of frequent occurrence, and mix with the writings and the reasonings of many who do not profess admiration for any logical system. We therefore propose to compress within the limits of a few chapters, such a compendious view of the science as may give at least a general idea of its leading terms and principles to those who may have hitherto neglected, or may not have enjoyed, the opportunity of turning their attention to the subject.

Such being the limited and humble object to which we expressly confine ourselves, it may not be improper to commence with a rapid historical outline.

Greece has the acknowledged honour of being the birth-land of logic; and Zeno, the Eleatic, who was born about six hundred years before the Christian era (and must not be confounded with another Zeno, the celebrated founder of the Stoics, who lived about two hundred years later), is generally described as the earliest writer on the subject. His work on Dialectics, as logic was then called, consisted, to a large extent, of logical puzzles, mixed with a portion of philosophy. The latter was neglected by the race of sophists who succeeded him, while they employed their ingenuity in multiplying quibbles and enigmas, founded on verbal ambiguities. His work, however, furnished to Socrates that *erotetic*, or interrogatory method, for which the Athenian sage was so famous in his disputations —a method which consisted in assuming that his adversary's tenet was correct, and in leading him, on that assumption, from one answer or inference to another, by a strictly catechetical process, until the assumed or supposed truth was found to involve one of two things—either contradiction or absurdity.

Socrates, who lived and taught about 450 B.C., was both a logician and moral philosopher, although it is chiefly as the latter, and as the instructor of a band of sages, that his name has been imperishably written in the world's annals. It is, however, no small merit of Socrates—perhaps it is his greatest and highest merit—that even while he lived in the most flourishing age of the sophists, and while he was unjustly selected and ridiculed, as the representative of the class, by Aristophanes, the dramatic poet, his logic was the logic of common sense, as his moral philosophy approached to the lofty morality of the gospel. Socrates left behind him no writings; but many of his doctrines and sayings are recorded in the works of his distinguished disciples, Plato and Xenophon, who speak of him with almost filial reverence. Instead of deserving to be classed with the sophists, this most illustrious and remarkable man exercised his natural shrewdness and his cultivated logical powers, in confuting their flimsy sophistries, and holding up their quibbles to ridicule.

Antisthenes, the founder of the Cynics, and Euclid, the Megarean, were both pupils of Socrates. The former pointed out the vast importance of a careful attention to definition; the latter rejected analogical reasoning, and first gave a formal structure to the *reductio ad absurdum*, or that mode of reasoning which consists in proving a truth by showing that the assumption of its falsity leads to some glaring absurdity.

But the greatest disciple of Socrates was Plato, born about 430 B.C. He pronounced ignorance the true starting-point for science; the mind was to be cleared, in the first place, of its preconceptions, and then, having freed itself from vulgar error, to store itself with accurate knowledge, acquired by philosophical reflection. Sensations, notions, and ideas, he regarded as furnishing, or constituting, what he termed the Intelligence. *Sensations* he referred to individualities; *notions*, to generalizations; *ideas*, to the invariable and universal. The logical operations of the mind he divided into—1. Definition; 2. Division; 3

Generalization; 4. Classification; 5. Hypothesis; 6. Deduction. And these resulted in two things—Truth and Opinion. There is much of the mystical in Plato's philosophy, and though his sublime speculations are expressed with inimitable beauty of language, it remained for a genius of a different cast to create into a regular system the science of logic.

Aristotle is, indeed, the father of logic. He gave it, for the first time, the form of a complete science, collected into one focus the scattered rays of light that had emanated from his predecessors, and vastly extended its boundaries by his original researches and additions, embracing a classification and nomenclature almost entirely his own. His name, in short, is identified with logic, as that of Euclid with geometry, Sir Isaac Newton with astronomy, or Watt with the steam-engine. Though Archbishop Whately denies, in opposition to Locke, that he was the *inventor* of syllogisms, "to which," says the former, "he certainly had no more claim than Linnæus to the *creation* of plants and animals, or Harvey to the praise of having *made the blood circulate*, or Lavoisier to that of having *formed the atmosphere* we breathe"—yet he was undoubtedly the first who distinctly developed the process of reasoning in the purely syllogistic form, and is, therefore, fully entitled to the honour of being its inventor, as exhibited in that form. This is all that Locke contended for, while, at the same time, he expressed no very high admiration of the Archbishop's favourite science; for he says, in his work on the Human Understanding, that "if syllogisms must be taken for the only proper instrument of reason [reasoning?] and means of knowledge, it will follow, that before Aristotle there was not one man that did, or could, know anything by reason; and that, since the invention of syllogisms, there is not one in ten thousand that doth."

But Aristotle's logical system, including his expositions of the syllogism, being in reality the science and the art of logic which we are about to explain, we postpone at present any details on the subject, to pursue our historical outline. In doing so, we shall find little advancement till recent times; for even Whately allows that logic was begun and finished by the Stagyrite, the teacher of Alexander the Great. "It has been remarked," he says, "that the logical system is one of those few theories which have been begun and completed by the same individual. The history of its *discovery*, as far as the main principles of the science are concerned, properly commences and ends with Aristotle." This appears to be a candid, if not a contradictory admission, by an author who will not allow that Aristotle *invented* the syllogism, although he *discovered* logic.

Aristotle was one of the pupils of Plato, with whom he spent twenty years in hearing his lectures, before he erected a school for himself, which, as a logical seminary, far eclipsed that of his master. Zeno, of Citium, the founder of the Stoics, lived about the same period, having been born about 362 B.C. The logic of this school is not very intelligible. Greater regard is paid to their moral philosophy, which, in a subsequent age, was fully expounded by Seneca, and which may be said to have consisted in the doctrine that, to the truly wise man, pleasure and pain, life and death, are indifferent—a doctrine leading to the exercise of self-denial, of fortitude, and equanimity in all circumstances. Pyrrho and Epicurus, both of them distinguished philosophers, flourished in the same age, but added no real improvement to Aristotle's logical system. Pyrrho is famed as the founder of the Sceptics—the author of the system of unbelief in philosophy. His favourite maxim was to doubt everything—even to discredit the reality of his own doubts. He held that all is contradictory, and therefore all is false—a system of belief which was unbelief, and which may have afterwards suggested to the Roman Governor of Judea the memorable question, "What is truth?" The Pyrrhonists seem to have forgotten that, if all is false and contradictory, so is their own philosophy—so is this very statement itself; for if it be true that all is false, it is false to say that nothing is true.

Epicurus, an Athenian, was born about 341 B.C., and founded the celebrated sect or school of the Epicureans. His opinions are fully expounded by the Roman poet, Lucretius, who died about half a century before the Christian era. He endeavoured to simplify the Aristotelian logic, but everything he touched was vitiated by his moral system. He held that, whatever our emotions accept gratefully, the same is good and true, and ought to be sought after; whatever they dislike is evil and false, and ought to be avoided. In accordance with this fundamental maxim was his logic, embracing the following characteristic rules for correct thinking:—1. Sensations never really deceive. 2. Error orignates in opinion. 3. Opinion is true when sensations confirm, or do not contradict it; and false when they contradict, or do not confirm it. 4. All general ideas are received through the senses. 5. General ideas are the elements of reasoning.

It thus appears, that while Pyrrho's philosophy was nothing but a labyrinth of doubt and distrust, that of his contemporary, Epicurus, was based upon a thoroughly sensual system, constituting pleasure the test of truth, and therein utterly opposed to the lofty morality of the Stoics, who looked upon enjoyment and suffering with equal indifference or contempt. Hence Dr. Beattie's exclamation in his beautiful poem, "The Minstrel:"—

> "O Nature! how in every charm supreme
> Whose votaries feast on raptures ever new!
> O for the voice and fire of seraphim,
> To sing thy glories with devotion due!
> *Blest be the day I 'scaped the wrangling crew,*
> *From Pyrrho's maze and Epicurus' sty;*
> And held high converse with the godlike few,
> Who to th' enraptured heart, and ear, and eye,
> Teach beauty, virtue, truth, and love, and melody.
>
> "Hence! ye who snare and stupify the mind,
> Sophists—of beauty, virtue, joy, the bane!
> Greedy and fell, though impotent and blind,
> Who spread your filthy nets in Truth's fair fane,
> And ever ply your venom'd fangs amain!
> Hence to dark Error's den, whose rankling slime
> First gave you form! Hence, lest the Muse should deign
> (Though loth on theme so mean to waste a rhyme)
> With vengeance to pursue your sacrilegious crime."

These are the sentiments of a poet, indeed; but they have been confirmed and approved by the calm, philosophical verdict of all ages. While Zeno's stoical school is still respected, and even commands the avowed admiration of such philosophical writers as Adam Smith, the doctrines of Pyrrho and Epicurus are now only mentioned to be deprecated.

But each of these distinguished philosophers was followed by a train of disciples. To Pyrrho succeeded Timon, the Phleasian, and others, who inherited, and skilfully defended with all the resources of sophistry, the sceptical creed of their master. Zeno, the Stoic, was succeeded by Cleanthes and Chrysippus. Epicurus had a crowd of followers, the chief of whom were Metrodorus, Hermachus of Mitylene, Polystratus, Dionysius, Zeno of Sidon, &c. In the meantime, the "New Academy" arose. This was instituted by Arcesilaus, who was born at Pitane, about 316 B.C., and who united, and endeavoured to reconcile into one harmonious system, the various philosophies of the age. Thus, the Socratic inquisition, or Erotetic system, the Platonic idealism, the Zenoic suspension of judgment, the sceptical incredulity of Pyrrho, the sensual philosophy of Epicurus, were all elaborately combined, and skilfully interwoven with the Aristotelian dogmas, in the "New Academy." Philosophy was jumbled, and truth lost, in a confused mass of inconsistency. Even the works of Aristotle fell into complete abeyance for a couple of centuries. Scepticism reigned triumphant in the general chaos of opinion; and "What is truth?" was a question which was generally asked with derision, when Christianity dawned—not, indeed, to sweep away immediately the ancient schools of philosophy, but to elaborate a new system, which ultimately led the "march of mind" to higher glimpses of truth, and the destruction of the most pernicious errors.

"The writings of Aristotle," says Whately, "were not only, for the most part, absolutely lost to the world for about two centuries, but seem to have been but little studied for a long time after their recovery. An *art*, however, of logic, derived from the principles traditionally preserved by his disciples, seems to have been generally known, and to have been employed by Cicero in his philosophical works; but the pursuit of the science seems to have been abandoned for a long time." We cannot refer to the writings of the Fathers in the earlier

ages of Christianity, as furnishing any exception to this general statement. The leading object of Justin Martyr, Tertullian, Origen, St. Augustine, and others, was to establish the harmony of Reason and Faith; but though they attempted to do so on certain logical principles, they did not pretend to write logical treatises, or to elucidate the science in a systematic form. The first strictly philosophic sect which appeared in the Christian era, was that which has been termed the Neo-Platonic, Eclectic, or Alexandrian school—a school which, taking Platonism as its foundation, endeavoured to incorporate it with truth derived from a variety of sources. To this school belonged Ammonius Saccas; his pupil and disciple, Plotinus (born A.D. 205); Porphyry, a logician of eminence; Jamblichus, Hierocles, and Proclus, the last of whom flourished in the middle of the fifth century (412—483). The Aristotelian or Peripatetic doctrines were now beginning to revive, and Aristotle's logical works were translated into Latin by Boethius, who died about A.D. 524.

But at this time occurs another remarkable blank—a period of almost absolute darkness, which lasted for nearly two centuries. These were the darkest ages of history, succeeding the decline of ancient literature, and ushering in the gloomy reign of the Schools. The venerable Bede (673—735) did something to restore a taste for learning; but it was not till the reign of Charlemagne (768—814) that the *scholæ*, or schools, were founded by that munificent prince, who endeavoured to make them the depositaries of all then existing science. This was the origin of the Schoolmen of the Middle Ages.

The first of these was Alcuin, a pupil of the venerable Bede, and the bosom-friend of Charlemagne. He wrote a variety of works, among which were one or two dialogues on grammar, rhetoric, and logic, possessing considerable merit. John Scotus Erigena, who flourished in the ninth century, acquired no little celebrity as a metaphysician. St. Anselm (1033—1109) was one of the most eminent logicians of his day, and his work, entitled "*The Monologium*," in which he attempts to show how an ignorant man, by the power of thought alone, might construct for himself a complete system of truth, affords a remarkable exemplification of that fundamental delusion which prevailed in the middle ages—a vain and presumptuous belief in the power of the human mind to reason out and elaborate for itself all necessary knowledge, without the preliminary drudgery of carefully ascertaining facts. Roscellinus, of Compeigne, who flourished about 1080, commenced the great middle-age discussion between Nominalism and Realism, a question which originated in the Greek philosophy, though not developed till the period at which we have now arrived. Plato maintained that universals (or ideas corresponding to general names, such as a man, a horse, a mountain) existed, in archetypes, in the bosom of God; Aristotle, that they were abstractions and generalizations from experience—the former, that they were *à priori;* the latter, that they were *à posteriori.* Roscellinus adopted the opinion that universals were mere words—names of conceptions, not conceptions themselves—and was, therefore, a Nominalist. This is a subject to which we may recur at a future period; we mention it at present merely to illustrate the subtle and barren disputations on which the ingenuity of the learned was in these days vainly expended, multiplying words without knowledge.

William, of Champeaux, who studied under Roscellinus, strenuously opposed the doctrines of his master, and maintained the realistic or Platonic creed, with distinguished zeal and ability. His fame was so great that Paris required to be enlarged to contain his pupils. This has been termed the Augustan age of scholastic logic. His pupil, Abelard, one of the most celebrated names of the middle ages, took again the opposite side, and defended Nominalism. Thus the controversy raged, as one school succeeded another, between the Platonic and Aristotelic systems. Hugo St. Victor, Richard St. Victor, Peter Lombard, John of Salisbury, and several other names, that were once famous, bring us down to the thirteenth century, when Thomas Aquinas appeared (1227—1274), who is reckoned the greatest philosopher of the middle ages. It may, however, be safely asserted, that he added little or nothing to the sum of human knowledge—that he even contributed little or nothing to point out the way to truth, or to assist the philosophical progress of the human intellect. A greater than he, in our comparative estimate, was his illustrious contemporary, Roger Bacon (1214—1294); a man similar, in the cast of his mind, to his great philosophical namesake of a future day. Despising the frivolous logomachy of the schools, he seems to have been really the first to perceive clearly, that although the art of logic, properly studied, *might* improve the reasoning powers, it never could directly extend the boundaries of human knowledge. He therefore applied himself to physical studies, pursuing, with an instinct in advance of his age, the path of observation and experiment; and no surer proof of his success can be given than that, by his attainments and discoveries, he incurred the persecution of his monkish brotherhood, by whom he was consigned to a dungeon, on the charge of having converse with the devil. He has left behind him incontestable evidence, concealed in cabalistic disguise, that he knew the composition of gunpowder, then a secret to the world—that he was acquainted with the properties of lenses, and had, indeed, anticipated many discoveries, which he was afraid to reveal to the logical philosophers of his age. These facts we mention merely to show that the study of logic, as then understood, or rather most grossly misunderstood, was really an impediment to all knowledge, and that it was a "darkening of counsel" under the shadow of a Church, which lay like a gigantic incubus on the human mind. Any one who dared, in these days, to question the all-sufficiency of the Aristotelian logic incurred the inexorable ban of the Vatican.

Having mentioned the name of Thomas Aquinas, we must also introduce that of Duns Scotus (1274—1308), surnamed *the subtle Doctor*, who was so decidedly opposed to the doctrines of his great predecessor, that the schools became divided into two sects; namely, Thomists and Scotists. This denominational controversy raged with remarkable virulence for many years; but it would be somewhat difficult, and would, perhaps, tend but little to the edification of the reader, to set forth the points of difference between the contending philosophical factions. Some idea of their real importance, though not of the importance which was then attached to them, may be inferred from the following short specimen:—"Ideas, said Duns Scotus, are either sensible or necessary, and absolute. All truth exists in the latter, the former being the *occasions*, not the *causes* of thought. Aquinas supposed that universal forms really dwelt in individuals. Scotus maintained that universal and individuative entities existed independently, and that by their junction the nature of things was determined; that universals reside in the mind as *powers*, and sensation brings them forth into *acts*." This may suffice, in the meantime, as a specimen of the learned trifling of the middle ages.

Passing over a couple of centuries, during which few names appeared that reflected lustre on philosophy, we find ourselves launched into the age of the Reformation, when, from the invention of printing and other causes, men's minds began to awaken to a clearer perception of the truth—to call the authority of the schools, as well as of the church, in question, and even to impugn the supremacy of Aristotle, who had been so long the infallible pope of philosophy. Peter Ramus (1515—1572) was one of the first, in this remarkable period, who daringly controverted some of the principal tenets of the Peripatetic philosophy—an independence and boldness of thought, a philosophical heresy indeed, for which he was publicly condemned of being "rash, impudent, arrogant, and ignorant." But neither in the schools nor in the church, could the light that had dawned be quenched, or the tide of independent thought be turned back. The mighty press had begun to achieve that resistless revolution which is still in progress, and which, in the course of three centuries, has done immeasurably more to extend the bounds of human knowledge than all the preceding ages of the world's history. When Ramus was so denounced for his rashness and ignorance, the celebrated Boileau published a satiric petition, craving an interdict against Reason and Experience, which would no longer submit to the laws of Aristotle. This poetical *jeu d'esprit* excited a laugh against scholastic follies; and then followed such men as Bacon, Descartes, Hobbes, Locke, Montagne, and Pascal, who further and finally contributed to bring into merited discredit the

frivolous and quibbling perversions of logic, which, under the name of philosophy, had so long usurped the dominion of the mind, and impeded the progress of knowledge.

The greatest name, in this revolution of philosophy, is that of our illustrious countryman, Lord Bacon (1561—1626), who published his *Novum* (New) *Organon*, expressly in opposition to the logical system of Aristotle, so named. Others had already commenced the work, but Bacon's was the master-mind which completed it—which overthrew, once and for ever, the barren logic of the schools, and pointed out the path to knowledge by careful observation and experiment. Hence he has been justly termed the father of the inductive philosophy. He showed the futility of mere reasoning unless there were facts to support it. The logicians of the schools had despised facts; argumentation was their sole employment. Bacon affirmed that knowledge could only be acquired by patiently *interrogating* nature—a knowledge of the facts of external nature, by attending to the processes of nature, or making experiments upon them—a knowledge of the facts of the mind itself, by faithfully interpreting our own consciousness, and building up general laws from a large induction of particulars.

To demonstrate this important view of philosophy was Lord Bacon's great achievement, to which he devoted his gigantic intellect, and which he not only explained and enforced, but likewise endeavoured to illustrate in his own philosophical works. From that time the logic of the Schools expired. The mind of man ceased to be amused with fancies, and began to grapple with facts. Even the legitimate logic was abandoned, and the vast field of nature was ransacked by diligent and careful observers in every department of physical science. Hence the incalculable progress which has been made in accumulating the facts and explaining the phenomena of nature, since the time when the Royal Society was founded, adopting as its basis the principles propounded by Lord Bacon.

Still, some celebrated men continued to prosecute metaphysical studies, and even to cultivate the science of logic in particular. Of these was Hobbes (1588—1679), a friend of Lord Bacon, who brought to the study of the art of reasoning a mind of remarkable acuteness, and of great scientific attainment. His works are consequently free from the puerile frivolities of the schools. In logic he adopted the Nominalist side, which he defended with characteristic ability. He truly maintained that exact definitions of *words* are necessary to attain the end of science, namely, demonstrative knowledge; but, pushing his theory so far as to say that truth is in *words*, not in *things*, he has been accused of a philosophy which saps the foundations of religion.

Nearly contemporary with Hobbes was Locke (1632—1704), whose work "On the Human Understanding" is much more generally known than any of the writings of the former. He looked with but little favour on the art of logic in general, spoke of the syllogism almost with contempt, and thereby incurs, as we have seen, the displeasure of Archbishop Whately. He asserted that reason is the superintendent of the whole machinery of thought; and that Reasoning consists of—1. Discovering proofs; 2. Arranging them properly; 3. Perceiving their mutual connection; and, 4. Employing them correctly.

To Locke succeeded Isaac Watts (1674—1748), who published two popular works on the subject—"Logic, or the Right Use of Reason," and "The Improvement of the Human Mind"—works, in which an effort is made to combine into a clear, intelligible system the most useful doctrines of the Schoolmen, of Aristotle, Bacon, and Locke, and which were the first to restore logic to some degree of general esteem, after the excessive refinements of the schools had exposed it to so much contempt and neglect. Another excellent treatise on the subject was published by William Duncan, Regius Professor of Philosophy in Aberdeen (1717—1760). The names of the great Scotch metaphysicians, Hume, Reid, and Dugald Stewart, who flourished about the same period, deserve to be prominently mentioned in connection with the art of reasoning, although they confined themselves chiefly to elucidate the mental processes of thought, and to trace the sources of knowledge. Dr. Campbell's "Philosophy of Rhetoric" (1762) contains many excellent views in connection with the *science* of logic, but condemns the study of the syllogism as unimportant.

Another metaphysical name of note is that of the celebrated German philosopher, Kant, the author of the Transcendental system (1724—1804). But although his logical doctrines are both profound and original, we cannot attempt, in a cursory notice like the present, to trace them even in outline.

Of still more recent writers who have largely contributed to elevate the study of logic, as well as to elucidate its true principles, our limits will only permit us to enumerate the most conspicuous names—those of M. Cousin and M. Auguste Comte, in France; and in Great Britain, Archbishop Whately, Sir William Hamilton, and John Stuart Mill. A galaxy of minor stars might be mentioned, but only, or chiefly, in the humbler capacity of *writers*; while those whom we have named above are distinguished as original thinkers, as propounders of new and enlarged views, and as standing in distinct pre-eminence at the head of the modern schools of logic.

We shall proceed, in our next chapter, to give an analytical outline, and then a synthetical summary, of the science.

MEMOIR ON TWO PROCESSES FOR THE PREPARATION OF ALUMINUM.

Read before the French Academy of Sciences, Aug. 14, 1854.

By M. Henri Saint-Claire Deville.

The discovery of the valuable properties of aluminum, which is the basis of clay, and therefore must be one of the most abundant metals, has lately attracted much attention in the scientific world. To separate the metal from its earthy combinations by a cheap and expeditious method, is the great object in view, and constitutes at present the subject of investigation by many scientific men of eminence. The following memoir on this subject, and on a new form of silicum, which was read before the French Academy of Sciences, August 14, 1854, by M. Henri Sainte-Claire Deville, will therefore be read with interest at the present time:—

I have the honour, said M. Deville, to present to the Academy the sequel of a work undertaken and prosecuted purely with a scientific view, but the result of which, confirmed by new experiments, conducts me still to the same practical conclusion. Aluminum, of which the most common clays may contain so much as 25 per cent. of their weight, is eminently fitted to become a metal in general use. I did not publish the methods which I employed to produce it; they required to be tested by experiments performed on a scale, indeed, still limited, but which I could not attempt with the funds set apart for my laboratory in the Normal School. I owe to the Academy the privilege of having been able to carry out these experiments, for which I take this opportunity of expressing myself deeply indebted.

Before entering on the subject of this memoir, I shall state at once, that all I have announced in the course of my former investigations, has been fully verified and confirmed since I have obtained the aluminum in some considerable quantity. Large medals which I have got struck, and plates of the metal which I submitted to the Academy, have undergone no alteration by exposure to the air; small ingots have been handled daily for several months without losing their lustre. In short, this substance is so unoxidizable, that it resists the action of the air in a muffle heated to the temperature for assaying gold: in the cupel, lead burns away, litharge melts beside the aluminum, which loses none of its properties. If this metal were alloyed with lead, it would evidently yield to cupellation.

Aluminum conducts electricity eight times better than iron, and therefore as well if not even better than silver.

The place which should be given to aluminum among the metals, in accordance with the principles of classification laid down by M. Thenard, ought to remove it from magnesium, zinc, and manganese, beside which it is at present classed. It should be made the type of a highly natural group—composed, in addition to this metal, of chromium, iron, nickel, and cobalt. They have a common character, to which I attach, in a theoreti-

cal view, the greatest importance; they are not attacked by weak or concentrated nitric acid, in the presence of which they are passive. This *passiveness*, very decided in the case of aluminum and chromium, both of the protoxides of which (if aluminum has a protoxide) are evanescent, is shown, in the case of iron, only in concentrated nitric acid, in which the production of the protoxide is impossible; it appears only very feebly in nickel and cobalt, the sesquioxides of which are unstable, and enter only with difficulty into combination; these two metals constitute the transition stages to manganese.

Aluminum, like iron, does not make an alloy with mercury, and takes scarcely any traces of lead; it gives, with copper, alloys of a light character, very hard and very white, even when the copper enters so largely as 25 per cent. into the composition of the mixture. It is characterized at the highest point by the property of forming with charcoal, and especially with silicum, a grey, granular, and brittle compound, crystallizable with the greatest facility. The planes of its cleavage appear to cross at right angles.

I shall give in this paper two methods for preparing aluminum, the only ones with which I am acquainted, and which I have often practised.

1. *Process by Sodium.*—Take a large glass tube, of 3 or 4 centimeters (1 to 1½ inch) diameter, and introduce into it from 200 to 300 grammes (6 to 9 oz.) of chloride of aluminum, which must be well isolated between two pieces of amianth. By one of the extremes of the tube, transmit into it hydrogen gas, well purified from air and thoroughly dried. In this current of gas, heat the chloride of aluminum by means of a chauffer, so as to expel the hydrochloric acid, the chloride of silicum and chloride of sulphur, with which it is always impregnated. Then introduce into the glass tube spherules as large as possible, each containing a few grammes of sodium, previously bruised between two leaves of well-dried filtering paper. The tube being full of hydrogen, fuse the sodium and heat the chloride of aluminum, which distils over, and is decomposed with incandescence, which can be greatly moderated, even to the point of arresting it entirely, if so desired. The operation is concluded when all the sodium disappears, and when the chloride of sodium that is formed has absorbed enough of the chloride of aluminum to be completely saturated. The aluminum then dissolves into a double chloride of aluminum and sodium, a very fusible and volatile compound. The spherules are then taken out of the glass tube, and introduced into a large porcelain tube, fitted with a receiver, and traversed by a current of hydrogen, dried and purified from air. This is heated to a bright red: the chloride of aluminum and sodium distils without decomposition; this is collected in the receiver, and after the operation all the aluminum is found in each of the spherules run into one or two big globules. These are washed with water, which still removes a little of the acid salt and brown silicum. To collect these globules into one mass, they are introduced, after being cleaned and dried, into a porcelain capsule, in which, while they are melting, a little of the distilled product of the previous operation is put—that is to say, of the double chloride of aluminum and sodium. The capsule being heated in a muffle to a temperature at least approaching the point of fusion of silver, all the globules will be seen to unite into a brilliant button, which is left to cool, and then washed. The melted metal must be kept in a covered porcelain pot, till the vapours of the chloride of aluminum and sodium, with which it continues always impregnated, have quite disappeared. The metallic button is found enveloped in a thin pellicle of alumina, proceeding from the partial decomposition of the melting.

It is obvious that the sodium might be replaced by its vapour, which is produced so easily, and the aluminum obtained in a very economical manner, by simply using an alkaline reducing agent.

2. *By the Pile.*—It has hitherto appeared to me impossible to obtain aluminum by the pile in aqueous liquors. I should even entertain an absolute belief in this impossibility, if M. Bunsen's brilliant experiments on the production of barium did not shake my conviction. Nevertheless, I must say that all the processes of this kind which have been recently published, for the preparation of aluminum, have given me no result.

It is by means of the double chloride of aluminum and sodium (Al_2, Cl_3 NaCl), of which I have already spoken, that this decomposition is effected. The aluminum bath is prepared by taking two parts by weight of chloride of aluminum, and adding thereto one part of dry and pulverized marine salt. The whole is mixed in a porcelain capsule heated to about 200° Cent. In a short time the combination is effected with disengagement of heat, and one obtains a liquid very fluid at 200°, and fixed at that temperature. This is introduced into a glazed porcelain vessel, which is kept by means of a chauffer at a temperature of about 200°. The negative electrode is a platinum leaf, on which the aluminum deposits, mixed with marine salt in the form of a greyish crust. The positive electrode is formed by a porous vessel perfectly dry, containing fused chloride of aluminum and sodium, in which dips a cylinder of charcoal* to conduct the electricity. To this point the chlorine is carried, and a little chloride of aluminum, proceeding from the decomposition of the double salt. This chloride would be altogether lost by volatilization, were it not for the addition of marine salt in the porous vessel. The double and fixed chloride is reconstituted, and the fumes cease. A small number of elements (strictly speaking, two suffice) are necessary to decompose the double chloride, which presents but a feeble resistance to electricity.

The platinum plate is removed when it is sufficiently charged with the metalliferous deposit. It is left to cool, the saline mass is rapidly broken, and the plate is again inserted in the current. A porcelain pot, enclosed in an earthenware vessel, is then taken and the crude matter detached from the electrode is melted in it. After cooling, it is treated with water, which dissolves a great quantity of marine salt, and a grey metallic powder is obtained, which is united into a mass by fusing several times successively, using as a flux the double chloride of aluminum and sodium.

The first portions of metal obtained by this process are almost always brittle. One may, however, by means of the pile, obtain as fine a metal as by the sodium process; but the chloride of aluminum must be employed in a purer state. And in fact, in the latter process, by means of the hydrogen, the silicum and sulphur are removed, and even the iron, which passes into the state of fixed protochloride, at the temperature at which the operation is conducted, whereas all these impurities remain in the liquid decomposed by the pile, and are removed with the first portions of reduced metal.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING: THE CALOTYPE, DAGUERREOTYPE, &c.

CHAPTER VIII.

LATEST PROCESSES ON PAPER.

"The future of Photography," says M. Le Gray, "is altogether in paper; I cannot too strongly engage the amateur to direct to it his whole attention and study, and there can be no doubt that we shall shortly be able to obtain upon that material all that can be desired in delicacy of execution, and still greater artistic effect. Every one will agree with me, that it is always more agreeable and convenient to have to take paper instead of glass, which is both heavy and fragile. It is for these reasons that I am compelled to think, that none of those precious results which can be obtained upon glass, will for one moment counterbalance the advantages of the processes on paper."

These remarks, and the improved processes on paper which we are about to give in a somewhat abridged form, are taken from a recently published translation of M. Gustave Le Gray's "Practical Treatise on Photography," for which the public is indebted to the Messrs. Willats of London. To this translation, or to the original work of M. Le Gray, we beg to refer those of our readers who wish to be acquainted with all the minute details and the various modifications of the processes described by the author. We shall, however, transfer to our

* The most compact charcoal dissolves very rapidly in the bath, and falls down in powder; hence the necessity of the porous vessel.

columns sufficient instructions for the amateur, to enable him to practise with success the most important of the latest improvements described by the French artist.

The grand achievement accomplished by the new process is, that it supplies a method of preparing photographic paper, which may be dried and preserved for several days in a complete state of preparation, requiring only to be kept from the light till used, and then, if exposed in the camera, affording very beautiful pictures without any new preparation, while at the same time the subsequent process of development may be postponed for several hours, or even for a whole day, till it suits the convenience of the artist. "By keeping paper thus prepared from the light," says M. Le Gray, "it will preserve its sensibility five or six days, or more, before exposure in the camera. In using the solution of aceto-nitrate (to be described afterwards), it may be preserved good ten or twelve days, but it is less sensible. This mode of operation is precious for travellers, since it dispenses with manipulations, so difficult when one is away from home. It is sufficient to carry with one, slides furnished with prepared paper, and a portfolio, shutting very closely with two divisions, in one of which is placed a reserve of prepared paper, and in the other the pictures which may be taken. You take two or three proofs of the same view, to be sure of having one good one [for the image is not visible when taken]. Only in the evening, or even later, on your return, you develop the image with gallic acid." The advantages of this process are obvious. Travellers may avail themselves of it to fill their portfolios with a perfect panorama of the beautiful, the grand, and the picturesque, without having previously acquired the art of drawing; and this, moreover, in a manner which no human pencil could imitate.

The process by which these results are obtained is termed the "dry method," in opposition to another in which the paper must be used wet, and which accordingly is termed the "wet method." The latter is the more rapid; but M. Le Gray gives a decided preference to the former; and, indeed, its advantages are obvious. The time is perhaps not far distant when paper completely prepared will be sold in the shops, requiring only to be placed in the camera, and afterwards developed by a simple process, to furnish the most beautiful delineation of any object required. We shall, therefore, have the "dry method" chiefly in view, in presenting the reader with the following details of the improved processes on paper:—

1. *Waxing the paper.*—This operation is not essential to success; but it is recommended as being, for most purposes, a very decided improvement. The object is to stop up all the pores of the paper, to give it the appearance and firmness of parchment, and thus to equalize the effect of the subsequent operations. It may be performed by placing on a levelling stand a tin plate, which is heated by a spirit-lamp or water-bath, while the operator rubs over it a piece of white wax. The wax will melt with heat, and when a good coating is received on the plate, the operator places his paper upon it, assisting its adherence with a card. The paper is withdrawn when it has imbibed equally, and then it is placed between several sheets of fine blotting paper, over which an iron, moderately hot, is passed to take up the excess of wax. "It is very essential," says M. Le Gray, "that the wax should be very equally taken up, and that none remain but in the texture of the paper. A well-prepared sheet ought to have no shining places on its surface when held against the light, and should be thoroughly transparent. The iron is hot enough when a drop of saliva boils without rolling off; a greater heat spoils the wax and stains the paper." We may add that, for waxing, a very thin paper is recommended, selected, however, with the usual precautions against water-marks, stains of iron, &c. The sheets should be cut half an inch larger each way than they are absolutely required.

2. *Iodizing the paper.*—The paper, being waxed, is next to be charged with iodine and other auxiliary ingredients. For several purposes the waxing, as already intimated, may be omitted, and in this case thicker paper should be used. The iodizing process is as follows:—In one quart of distilled water, and in an earthen vessel, boil about three ounces of rice, which should be only slightly broken in order that the liquid obtained may not be thickened by an excess of amidine. Filter the liquor through a piece of linen, and dissolve in it the following ingredients to a quart:—

Sugar of milk,....................................	11	drachms.
Iodide potassium,....................................	4	do.
Cyanide potassium,....................................	12	grains.
Fluoride potassium,....................................	8	do.

When these substances are well dissolved, filter the whole through a piece of fine linen, and preserve the liquid in a bottle to use as required. It will keep for a long time without alteration, and serve to the last drop, so that a considerable quantity may be prepared at once, preserving the proportions above stated.

To prepare the paper, pour some of the solution into a large dish, and plunge the waxed paper, sheet by sheet, completely into it, the one upon the other, taking particular care to avoid air bubbles. Fifteen or twenty sheets may be thus treated at a time, and left to soak in the solution from half an hour to an hour, according to the thickness of the paper. The mass is then to be turned over, and beginning with the first sheet immersed, they are successively removed and suspended on a line to dry. The dropping liquid is gently removed from the lower edges by a piece of blotting paper. French and English papers, having different chemical qualities which act upon each other, must not be mixed in this process in the same vessel.

The paper thus prepared is almost insensible to light, and the preparation may be made in daylight; but, nevertheless, it is better to avoid a prolonged exposure, and to keep it from the action of any strong light. When perfectly dry, it should be cut to the size of the camera, and kept in a portfolio until it is about to be subjected to the next process.

3. *Exciting or giving sensibility to the paper.*—For papers prepared in advance, and designed to be employed either wet or dry *long after the time of preparation*, the following solution must be made in a well-stoppered bottle, and mixed either by the light of a taper, or in a place to which very little light is admitted:—

Distilled water,....................................	$2\frac{1}{2}$	ounces.
Nitrate of silver,....................................	40	grains.
Acetic acid,....................................	96	do.

The acetic acid should be added when the nitrate of silver is dissolved. The bottle containing the solution must be carefully excluded from the light, by keeping it in a covered case.

For waxed paper that is to be employed dry, *without preserving it more than four days*, the following solution is recommended as better:—

Distilled water, ...	$2\frac{1}{2}$	ounces.
Nitrate of silver,....................................	80	grains.
Acetic acid,....................................	96	do.

The solution, prepared in either of these proportions, is applied as follows:—Take two porcelain troughs rather deep; in the first put some of the solution; in the other, some distilled water. Plunge the waxed and iodized paper completely into the aceto-nitrate of silver in the first trough, and leave it there four or five minutes; then withdraw it, and immediately put it in the second trough among the distilled water, where you leave it at least four minutes, and longer if you mean to preserve the paper a long time before use. Ten or twelve sheets, one after another, may thus be prepared in the same baths. The paper, when taken from the water, is dried between blotting paper very clean and new; and then placed, to preserve it, between the leaves of a quire of the same paper, equally new and good. This paper, M. Le Gray adds, must not be dried by suspension in the air, as in that case it would change and become quite black in the subsequent process with the gallic acid; but it must be dried naturally, as stated, between blotting paper, putting alternately a sheet of prepared paper and a sheet of blotting paper.

Paper thus prepared, if kept from the light, will, as already stated, preserve its sensibility five or six days, or more, before exposure in the camera; and that prepared with the former of the two aceto-nitrate solutions above given, may be preserved good twice as long, but is less sensible. The editor of the translation of M. Le Gray's work states, that he obtained a

picture in London on paper prepared ten days previously in Paris.

4. *Exposure in the camera.*—" By the dry method," says M. Le Gray, " the time of exposure in the camera is not longer than in the wet method; it is perhaps shorter, only it requires more time afterwards in the gallic acid, to which is added fifteen or twenty drops of aceto-nitrate of silver, filtered and quite fresh. However short may have been the time of exposure, it must be well understood that you can always obtain the image by leaving the proof a relatively longer time in the gallic acid. It is my opinion, that the image is formed from the first moment that the luminous rays transmitted from the object lens strike the sensitive paper. All amateurs of photography should direct their researches in this direction, and seek a reactive to develop this image with power. To give an instance of this: I have taken the same view twice at the same time; to the first I gave twenty seconds in dull weather in the shade; to the second fifteen minutes, while the result obtained was the same, only the first appeared but after a stay of a day and night in the gallic acid, while the second was completely out in an hour."

He adds—" I cannot state exactly the time of exposure to the light; experience alone can determine it. Upon this time of exposure depends all the beauty of the image. I do not know how to impress this too much upon the attention. For a portrait in the shade, with the sensitive preparation of aceto-nitrate given above, and a double combination lens to cover the whole plate, I give between three seconds and one minute, and in the sun from one to ten seconds; and with waxed paper, employed dry, from fifteen seconds to a minute in the shade. The time should also vary according to the colour of the objects to be reproduced. Thus, for example, with an equal light, a monument will want thirty seconds of exposure, whilst forest trees will require, perhaps, twenty minutes for reproduction. Heat is also a great cause of acceleration. Thus, by warming the slate which carries the prepared paper, you operate more quickly; but in that case it is necessary that the lens be heated to the same temperature; if not, it will be covered with vapours which will hinder the formation of the image."

When the exposure is terminated, the image is scarcely apparent, and is only developed by the succeeding operations, which, with waxed paper used dry, may be performed even one or two days after.

5. *Development of the image.*—For this process the following simple preparation is used:—

Distilled water,..................................	1 quart.
Gallic acid,..	1 drachm.

Some of this solution is poured into a shallow trough, and the proof is completely immersed in it, so as to be covered on both sides. The development is easily seen through the thickness of the paper. It must be left in the solution from ten minutes to one or two hours, and sometimes longer, until it has arrived at perfection. If the paper has been waxed, it may be left one or two days without inconvenience, when the exposure in the camera has been very short—five or six seconds, for example.

The action of the gallic acid is strikingly accelerated by adding fifteen or twenty drops of aceto-nitrate of silver when the image begins to be developed. By this means very intense blacks are procured; but the action in this case must be closely watched, because it is so rapid, and there is a risk of having them too powerful if the process is too long continued. When the image is very vigorous, withdraw it promptly, and wash it in several waters, rubbing the back lightly with the finger to remove any crystalline deposits. The grey tint assumed by the waxed proof in this process will afterwards disappear, when the transparency is restored by heat, and the blacks and whites will be developed in a very beautiful manner. This operation may be much accelerated by heating the gallic acid.

6. *Fixing the negative proof.*—A negative proof has now been obtained, but the image is not permanent. After having washed it in water, it is thus fixed:—Make in a bottle the following solution:—

Filtered water,..................................	8 parts.
Hyposulphite of soda, ...	1 part.

Put a small quantity of this solution into a trough, and completely immerse in it your proof, taking the usual precautions to avoid air bubbles. The same solution may be used for several proofs, but put into it only one at a time. When the iodide of silver is completely dissolved, which will be known by the entire disappearance of the yellow tint it communicates, the paper will become remarkably white and transparent, and the dark parts of the image will be finely developed. With the waxed paper, from ten to fifteen minutes suffices for this purpose; with the ordinary papers, from half an hour to three quarters is required for the fixing.

The proof is then to be washed in several waters to remove the hyposulphite, and finally left for half an hour in a basin of water. It may then be dried by suspending it from one corner. Nothing but the black gallate of silver now remains in the paper, and the proof thus fixed is completely unalterable in the light. " I have negatives thus prepared," says M. Le Gray, " which have already furnished me 200 and 300 picture proofs, and of which the last are as fine as the first."

7. *Giving transparency to the negative proof.*—To procure pictures from negatives, the latter must be rendered as transparent as possible. For this purpose, if the proofs have been obtained on paper previously waxed, they are not to be waxed again, but are simply to be brought near to the fire, in order to restore to the wax its transparency, which has been removed by the successive immersions. The spots which these have produced will disappear when the transparency is restored in this manner.

If the paper has not been waxed, and the negative proof is strong and good, the transparency and strength of the paper may be greatly increased by waxing after the proof is obtained. This operation may, therefore, be performed (in the manner already described) at this stage of the process. But if the negative proof is feeble, and the paper very transparent, it is better to make the pictures without waxing.

8. *Producing and fixing the positive proof.*—Ample directions for taking positives from negatives were given in our second chapter (vol. i. p. 602), to which we refer the reader for details. There are, however, some peculiarities in M. Le Gray's process which deserve attention, and therefore we shall follow up his improved method of taking the negative proofs, by an outline of his suggestions for making positive copies by means of the reversing frame.

For this purpose he directs to make, first, a saturated solution of chloride of sodium (common salt), or, better still, hydrochlorate of ammonia. To one or other of these saturated solutions (preferring the latter, if convenient), three parts by volume of filtered water are added to one of the solution.

In another bottle, containing 100 parts of distilled water, dissolve 20 parts of crystallized nitrate of silver.

For the positive proofs, take stout white paper, cut the proper size, and free from iron spots and other impurities. Pour a little of the two solutions on two separate slabs or flat surfaces; choose the rough or most absorbent surface of the paper, and mark it with pencil; place it on the bath or slab of chloride of sodium, taking care that the other side is not wetted, and leave it from two to four minutes; then dry it thoroughly between several leaves of blotting paper, and while it is drying two or three other sheets may be treated in the same manner. When the first sheet is quite dry, put the prepared side on the nitrate slab; if left for a short time, the tint of the picture procured will be reddish-brown; if left a long time, a blackish tint is obtained.

This preparation must be made in the dark, or by the light of a taper or candle with a yellow shade. " You must not prepare the paper," says M. Le Gray, " more than eight days in advance, as time will blacken it, even in the dark, as well as exposure to light." It is better to prepare it in the evening and use it the next day, that it may be thoroughly dry before putting the negative upon it, otherwise the latter is apt to be spotted and spoiled with the nitrate of silver.

M. Le Gray uses a further precaution against this. " I always put a sheet of paper," he says, " very transparent and waxed, or a sheet of paper glazed with gelatine, between the negative proof and the positive cliché. This in no way hurts the

sharpness of the impression, and preserves the negative from contact with the nitrate of silver, which might injure it." He, therefore, directs as follows:—Place the negative proof upon the lower glass of the pressure or reversing frame; put upon it a sheet of highly glazed or transparent paper, then a sheet of the positive paper—the prepared side upon the cliché; then place above that a sheet of black paper, and the second glass of the frame upon it; shut down the cover, which exercises a slight pressure on the glasses, to be sure that the contact is perfect. I always take care to leave a border outside the frame, both of the cliché and the positive paper, that I may judge of the action of the light. Expose the frame to the light of the sun in such a way that the rays will fall perpendicularly upon the proof; you will judge of the progress by the border outside of the frame.

The positive will take successively the following tints, at any one of which the process may be stopped:—Greyish-blue, neutral tint, violet-blue, indigo, black, bister-black, sepia, yellow-sepia, yellowish-red, greenish-grey, always more and more powerful until the oxide of silver is reduced to the metallic state.

When the desired tint is obtained, the action of the light is arrested, and the positive proof immediately fixed by the following operation:—

In one bottle dissolve one part of hyposulphite of soda in six parts of filtered water.

In another bottle dissolve 1-20th part of nitrate of silver in a glass or two of water; add to it saturated solution of chloride of sodium until the white precipitate ceases to fall; allow it to repose a short time, and then decant off the clear liquor. Take the white precipitate (chloride of silver), and dissolve it in the other bottle of hyposulphite. The older the hyposulphite the better.

The proof, to be sufficiently fixed, must remain at least an hour in this solution; to obtain the sepia and yellow tints, it may remain three or four days. The operation is intensely accelerated by heating the hyposulphite; but in that case the rapidity of action is so great that the process must be strictly watched. All the tints, from the red to the black and clear yellow, may be obtained by leaving the proofs a longer or shorter period in the bath. When the proof is the desired colour, wash it in several waters, and leave it two or three hours in a basin of water, until, touching it with the tongue, you perceive no sweet taste, which indicates the presence of hyposulphite of silver. Then dry it by hanging it up, and it is finished.

You may put as many proofs as you please in the bath of hyposulphite, taking particular care, however, to get rid of air bubbles between the sheets; and when any peculiar effect is desired, only one proof can be put in the bath at a time. "The taking positive proofs," remarks M. Le Gray, in conclusion, "requires great care and attention, and must not be treated as a secondary operation." With proper care, however, it cannot fail of success, and the positives thus obtained will vie with the finest results of the art either on glass or silver plates. It has likewise the invaluable advantage, that by multiplying positives in this manner—which may be done to almost any extent,—they may be employed to illustrate publications, and will be found very enduring.

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER XI.

To describe the cam in fig. 75.—Draw the radius, *a m*; find the centres of the various arcs, as at *b*, *c*, *d*, *e*. Draw a line, *a′ m′*, fig. 76, corresponding, to *a m*, fig. 75, and from *a′*, with *a m*, describe a circle, *a′ m′*. From fig. 75 take the distance, *a c*, *b c*, *m c*, *m b*; and from *a′ m′* describe arcs cutting in *b′ c′*. From fig. 75 take *a d*, *a e*, *f d*, *f e*; and from *a′ f′* describe arcs cutting in *d′ e′*. From *b′ c′* describe arcs, meeting those described from *d′ e′*—from *a′* describe a portion of a circle, meeting the arcs described from *d′ e′*. Finish as in fig. 75.

To draw the parallel spiral in fig. 79.—Draw a line, *a b*, fig. 80. Let *c d* be the distance between the spirals; divide *c d* in *e*; from *e*, with *c d*, describe a semicircle, *c d*. From *d* as a centre, with *d e* as radius, describe the semicircle, *c f*; from *e* as centre, with *e f* as radius, describe the semicircle, *f g*; from *d*, with *d g*, describe a semicircle to *h*; from *e*, with *e h*, describe another to *a*, and with *d a*, from *d* describe another to *b*. The inner line in fig. 79 is obtained from the same centres, but with less radii.

To describe the Archimedian spiral in fig. 81.—Let *c d* be the point through which the last convolution is to pass, and *c* the centre of the spiral. Divide *c d* into as many equal parts as there are to be turns or convolutions in the spiral, as five. From *c*, with *c d*, describe a circle (not shown in the diagram) and draw the radii, *d i*, *g k*, *h l*, *q f*, making eight equal angles with each other. Divide each of the divisions (five) on the line, *c d*, into eight equal parts, equal in number to the angles formed by the radial lines. To avoid confusion, the line, *a b*, is divided. From *c*, with radius *b* 1, cut the radial line, *q f*, in *f*; with radius *a* 2, from *c* cut the radial line, *k g*, in *g*; with radius *a* 3, from *c* cut the radial line, *h l*, in the point *h*; with *a* 4, from *c* cut *d i* in *i*; with *a* 5, *f j* in *j*; with *a* 6, *g k* in *k*; with *a* 7, *h l* in *l*; and with *a* 8, *d i* in *e*. Proceed thus, lessening the distance in the compasses each time a distance equal to a division on *a b*, and setting this off from the centre, *c*, on the radial lines to the points *m*, *n*, *o*, *p*, *q*, *s*, *t*, *u*, *v*, *w*, *x*, *y*, *z*, 1, 2, 3, 4, 5, 6, 7, 8, 9. Through these points thus obtained, draw by hand the curve. It is obvious that the more numerous the radial lines as *g k* are, the more correct will be the curve of the spiral.

To delineate the eccentric casing of a horizontal water-wheel or turbine in fig. 82.—First find the centres of the various arcs forming the outline of the figure, and draw two diameters in the internal circle, *f*. The centres will be found at *a b*, *c d*, *e*. In fig. 83 describe the circle, *f*, and draw two diameters corresponding to those in fig. 82. From the points *h g*, with the distances *h b*, *g b*, describe arcs cutting in *b*, fig. 83. With distances *f a*, *g a*, from the points *f g*, fig. 83, describe arcs cutting in *a*. With distances *i d*, *f d*, fig. 82, from points *i f*, describe arcs cutting in *d*. With distances, *g c*, *i c*, from points *g i*, describe arcs cutting in the point *c*, fig. 83. From the points *g i*, fig. 83, with distances *g e*, *i e*, fig. 82, describe arcs cutting in *e*. From *d*, with *d m*, fig. 83, describe the arc *m n*. From *a*, with *a n*, describe another arc, *n o*. From *e*, with *e o*, describe another arc, *o p*. From *b*, with *b p*, another arc *p s*. And from *c*, with *c s*, another to *t*. Finish as in fig. 82.

To draw the eccentric casing in fig. 84.—Find the various centres as at *a*, *f*, *b*, *c*, *d*, *e*. Draw lines, *i j*, *g h*, at right angles through the centre, *f*. In fig. 85—draw a line, *g h*, and from *a f* describe circles equal to those in fig. 84. With *j c*, *i c*, fig. 84, as radii from points *i j*, fig. 85, describe arcs cutting in *c*. With *j b*, *g b*, from fig. 84, from points *j g*, fig. 85, describe arcs cutting in *b*. With *j e*, *h e*, fig. 84, from points *j h*, describe arcs cutting in *e*, fig. 85. With *h d*, *j d*, fig. 84, from points *j h*, fig. 85, describe arcs cutting in *d*. From *b*, fig. 85, with *b k* (obtained from fig. 84) describe an arc, *k b*. From *c*, describe another to *m*. From *d* describe another to *n*, and from *j* another to *g*—all these arcs will join each other, and form the outline of fig. 84.

To describe the spiral armed disc, or wheel, in fig. 88, with radius, *a e*, fig. 88, describe the circle, *a e*, fig. 89. Within this describe any number of concentric circles; and from *a*, fig. 88, describe the same number; draw, in figs. 88, 89, radial lines, the same number in both figures. Mark the points through which the arms pass; the radial lines and concentric circles, as *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, and terminating at *e*. The points of one line, or arm, being thus found, the whole of the curves may be drawn in by the hand. Each arm starts from the small central circle, *a*, fig. 88, at the points where the radial lines, *b*, *c*, *d*, *e*, *f*, *g*, *h*, and *a*, cut this circle, as in fig. 89. Suppose fig. 88 to be the copy of a diagram, to be delineated, same size, by the learner; the radial lines, and concentric circles, may be drawn lightly, in pencil, over its surface; and afterwards rubbed carefully out, after the fac-simile is constructed. This method is applicable to a large number of subjects.

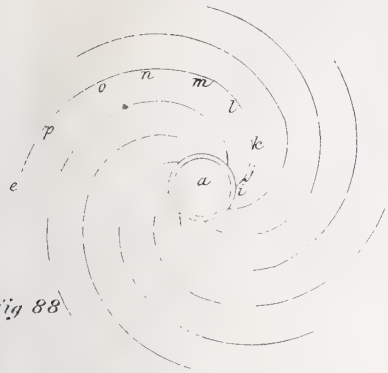


Fig 88

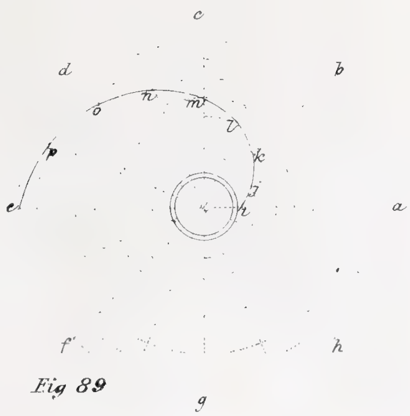


Fig 89

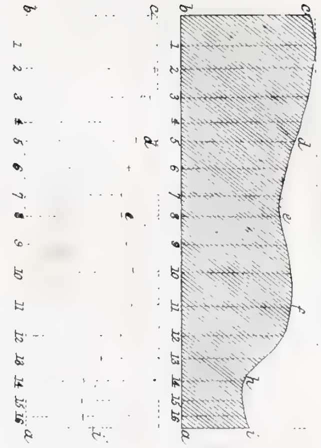


Fig 91 Fig 90

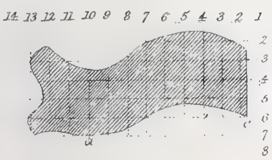
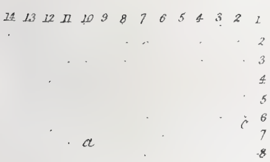


Fig 92



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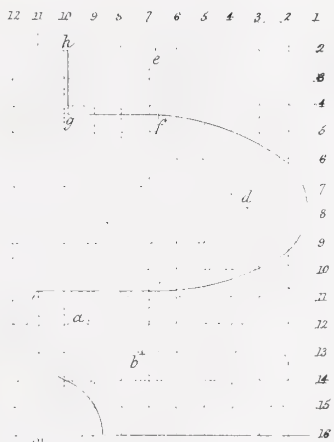

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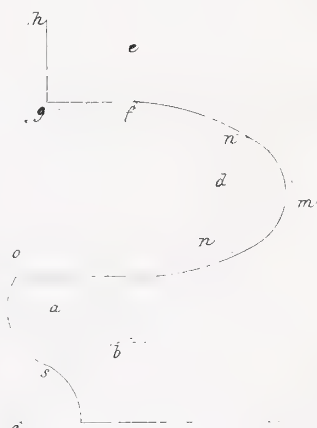
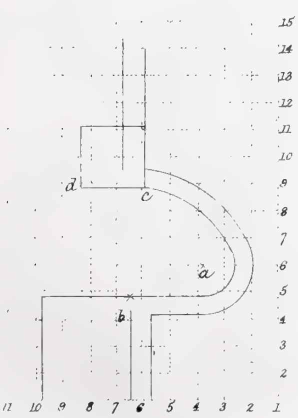


Fig 95

Fig 96



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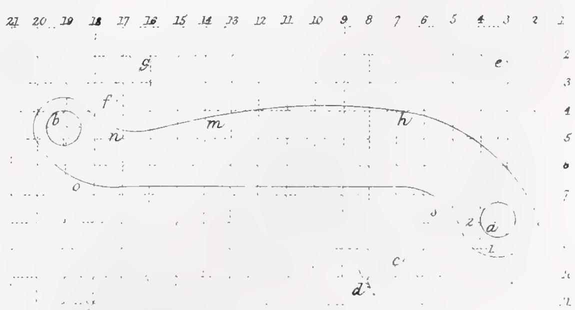

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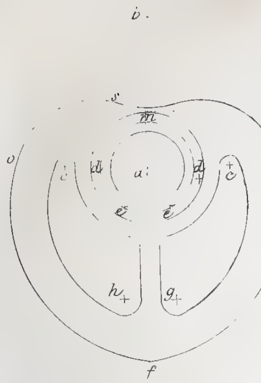
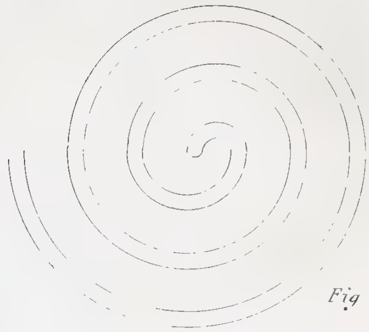


Fig 77

Fig 78



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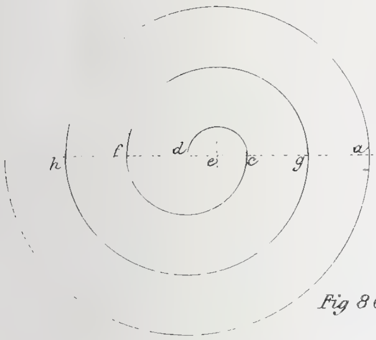

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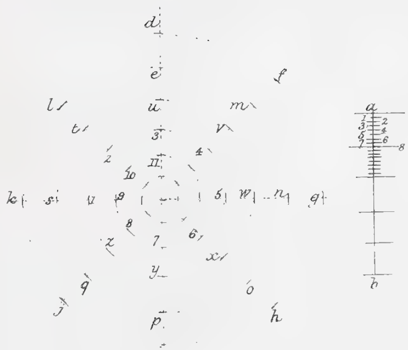

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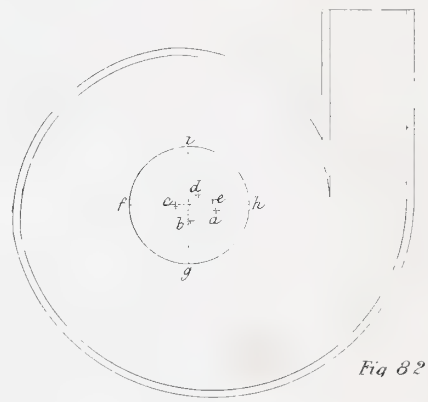


Fig 82

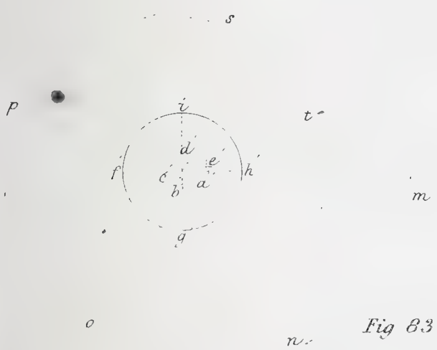


Fig 83

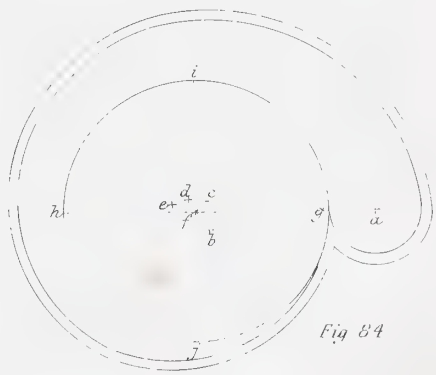


Fig 84

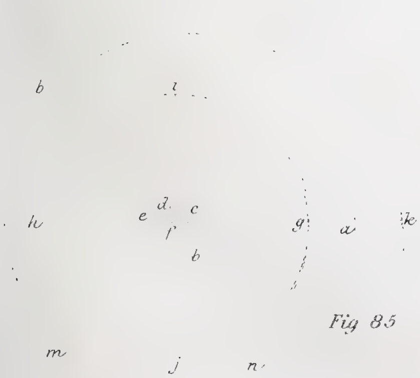


Fig 85

Fig 86

Fig 87

TERMS USED IN MECHANICS.

II. HYDRAULIC ILLUSTRATIONS OF ACCUMULATED POWER.—REACTION OF WATER.

If a body of water fall through a height expressed generally by h feet, its mechanical efficiency will be indicated, agreeably to the definition of labouring force formerly given, by $w \times h$, taking w as before, to represent the weight of the body of water.

Thus, supposing the numerical value of h to be 20 feet, and the quantity of water to be 10 cubic feet per second, $= 10 \times 62\frac{1}{2}$ lbs. $= 625$ lbs., the labouring force will be expressed in horse-power by

$$\frac{(625 \times 20) \times 60}{33000} = 11{\cdot}272 \text{ nearly,}$$

which, on an overshot water-wheel yielding 75 per cent. of effect, will be $11{\cdot}272 \times {\cdot}75 = 8{\cdot}454$ horse-power as the available labouring force of the water.

But in a stream flowing with a known velocity, the value of h must be ascertained from that velocity before our formula of calculation can be applied. In this case the water glides down an inclined plane, the fall in which is expressed by the relation

$$h = \frac{v^2}{2g}$$

that is by the quotient arising from the division of the square of the velocity by twice gravity $= 64{\cdot}4$.

Thus, supposing the ascertained velocity to be 5 feet per second, then $v^2 = 5 \times 5 = 25$ and

$$= \frac{v^2}{2g} = \frac{25}{64{\cdot}4} = {\cdot}3882 \text{ feet,}$$

which is *virtually* the perpendicular height of the plane of the channel whatever be its length. We say *virtually*, for the channel not being perfectly smooth, the water will encounter a certain amount of resistance from the inequalities and irregularities of the bottom and sides, which, together with its own cohesive attraction, will diminish the velocity due to the *actual* height of the plane: but the effective height being determined from the actual velocity, must be less than the actual height by the part expended in overcoming the combined resistances which the water encounters in its progress, and which, if the plane be of considerable length, will exceed the virtual height.

The mechanical efficiency of the stream—that is, the labouring force accumulated, being thus found, the value of h, may be calculated by the same formula as before. Thus, supposing the quantity of water to be 100 cubic feet $= 6250$ lbs. flowing through the channel per second, the power will be that of

$$\frac{(6250 \times {\cdot}3882) \times 60}{33000} = 4{\cdot}411 \text{ horses,}$$

which on a stream-wheel yielding 30 per cent. of the power of the water, will give $1{\cdot}3233$ horse-power as the effect available for doing work.

Reaction of Water.—The question of the reaction of effluent water, is one of much importance in hydraulics, and derives additional interest from its having particularly engaged the attention of Sir Isaac Newton, and several of the best mathematicians of later times. But to render the subject intelligible, it is necessary, in the first place, to explain the conditions under which it has been investigated.

As a preliminary step it has been experimentally ascertained, that if a small orifice be made in the bottom of a large vessel kept constantly full of water to a given height, the velocity with which the water issues is equal *nearly* to that which is due to the height of the surface of the water over the orifice. In other words, the velocity with which the particles of the fluid escape at the orifice is *nearly* the same as that which a heavy body—a ball of lead for example—would attain by falling from a height equal to the depth of the water in the vessel, and which is expressed by the formula $v = \sqrt{2gh}$.

Thus, supposing the depth of the water upon the orifice to be 2 feet, then the velocity v with which the particles escape will be $11{\cdot}35$ feet per second nearly, for if $h = 2$, then

$$v = \sqrt{2gh} = \sqrt{64{\cdot}4 \times 2} = 11{\cdot}35 \text{ nearly.}$$

In the statement of this proposition we have used the qualifying particle *nearly*, to intimate that the accuracy of the general conclusion is affected by several circumstances. If the orifice be suddenly opened on the outside, the rule by which we find the velocity of falling bodies applies strictly to the first particles of effluent water which issues under the entire pressure of the superincumbent column; but as the efflux proceeds, nearly the whole mass of fluid is put in motion, and the particles approaching the orifice in converging curves are not expelled by the same pressure. Their mutual attraction also retards this escape; and their oblique motions arising from their converging as they descend towards the centre of the orifice, prevent their passing out in lines parallel to the axis of the jet. The effect of these causes is a contraction of the issuing stream at a small distance beyond the orifice forming what is called the contracted vein *(vena contracta)* the circumstances of which may be shown by experiment.

Thus, if we fill a tall transparent vessel with water in which is suspended a quantity of finely pounded amber, or other highly pulverised material, as nearly as possible of the same specific gravity as water, and open a small orifice in the bottom, the particles of the powder will render the movements of the water in the vessel obvious, for, being of the same specific gravity as the water, they become mechanically a part of it, and must therefore obey the same laws which regulate its efflux.* As the water flows out, it will be observed that at a distance three times the radius of the orifice from the bottom, the opaque particles begin to arrange themselves in curved lines, which are convex towards the axis of the vessel, and through which they approach the orifice with a velocity continually accelerating as to a centre of attraction. Now, these particles being, as before observed, mechanically a part of the moving fluid, show the conditions under which the water approaches the orifice inside of the vessel; they define the effect of the accelerated movement of the current and render visible the converging conoid thereby formed. They also inform us that the portion of water round the conoid, upon the bottom of the vessel, remains stagnant and allows the conoidal current to pass throughout it as if it were a solid body of ice.

When the position of the orifice is changed from the bottom to the side of the vessel, the circumstances of the experiment being otherwise the same, it is observed that the same conical funnel is formed by the concurrency of the particles to the orifice.

This convergence, which is observed inside of the vessel, is also observed to be continued a short distance beyond the orifice, and that the fluid vein, after escaping gradually, contracts, till having arrived at the point where the particles, gradually losing the oblique motion originally communicated to them, take a direction parallel to the axis of the jet. The vein formed is thus a species of truncated cone of which the greater base is the area of the orifice, and of which the lesser is the sectional area of the stream at the point of greatest contraction, and which is termed the section of the contracted vein.

This figure, and all the phenomena of the contraction, are usually referred to the convergence of the filaments of the fluid at the moment they arrive at the orifice; and if we could suppose the plate in which the orifice is formed to be infinitely thin, the explanation would be complete, for then we might suppose the oblique motions to be continued through the plate, and to become neutralized by the equal and mutual antagonism of the concurring filaments at the point where they attain the full velocity due to the pressure,

* The neatest way of making this experiment is to fill the vessel with a very weak solution of common salt, and to add a few drops of nitrate of silver; this will give a fine white precipitate of chloride of silver, which will be uniformly diffused by stirring.

that is, at the point of the greatest contraction of the jet. But the plate in which the orifice is formed having always a sensible thickness, the particles of water will adhere to and be obstructed by the periphery of the orifice, as in passing through a pipe, and consequently will have a greater velocity at the axis than towards the circumference where the retardation is greatest. But in consequence of the mutual attraction of the particles of the fluid, the whole will tend to a common velocity; for those having the greater velocity at the axis must of necessity accelerate those external to them and the converse, and thereby continually and proportionally diminish the area of the action of the vein till the maximum velocity of the jet is attained. The *length* of the conoid formed outside of the orifice may therefore be regarded as a measure of the time in which the issuing stream attains its maximum velocity, that is the velocity due to the mean pressure under which the particles leave the orifice; and from what has been here premised, it might be predicted that the maximum velocity will be different for different orifices. Accordingly, it has been determined experimentally by Michelotti that, with a circular orifice of an inch diameter in tin-plate, the velocity is only about one-hundredth part less than that due to the whole head of water; but when a tube of the same diameter and length was attached, the velocity was reduced $17\frac{1}{2}$ per cent.

From the same cause it may be easily imagined that different experimenters have found different relations to subsist between the area of the orifice and that of the section of the contracted vein, according as the orifice was of greater or less diameter in proportion to the thickness of the plate in which it was formed. Accordingly Newton, who was the first to examine the phenomena, states the area of the orifice to that of the section of the contracted vein, to be in the ratio of $\sqrt{2}$ to 1; consequently, making the diameter of the orifice unity, that of the vein would, according to his measurement, be ·841. "I procured," he observes, " very thin plate having a circular hole pierced in the middle, of $\frac{5}{8}$ths of an inch diameter; and that the stream of effluent water might not be accelerated by falling, and by that acceleration become contracted, I fixed this plate, not to the bottom, but to the side of the vessel, so as to make the water issue in the direction of a parallel to the horizon. When the vessel was filled, I opened the hole to let the water escape, and the diameter of the stream, measured with great accuracy at the distance of about half an inch from the hole was $\frac{21}{40}$ of an inch. The diameter of this circular orifice was therefore to the diameter of the stream very nearly as 25 to 21. The water in passing through the orifice, thus converges on all sides, and after it has run out of the vessel diminishes in volume by converging in that manner, and by contracting in volume is accelerated till it comes to the distance of half an inch from the orifice, and at that distance flows in a small stream, and with greater celerity than in the orifice itself, and that in the ratio of 25×25 to 21×21, that is, in the ratio of $\sqrt{2}$ to 1 very nearly. Now, it is certain from experiments* that the quantity of water running out in a given time through a circular hole made in the bottom of a vessel is equal to the quantity which, flowing with the aforesaid velocity, would run out in the same time through another circular hole, whose diameter is to the diameter of the former as 21 to 25; and, therefore, that running water, in passing through the hole itself, has a velocity downwards equal to that which a heavy body would acquire in falling through half the height of the stagnant water in the vessel nearly. But after it has run out, it is still accelerated by converging till it arrives at a distance from the hole nearly equal to its diameter, and acquires a velocity greater than it had there in about the ratio of $\sqrt{2}$ to 1—which velocity a heavy body would nearly acquire in falling through the whole height of the water in the water."—(*Prin., Lib. II., prop.* 36.)

Subsequent experiments have shown that the ratio here stated is too high for *thin* plates; but may, nevertheless, have been accurately ascertained for the particular thickness of material employed in the experiment. Taking the diameter of the orifice as 1, Poleny found that of the least section of the stream = ·79; Borda made it = ·804; Michelotti nearly the same as Poleny, namely = ·792; Bossut found it to vary from ·812 to ·817; Eytelwein made it ·80; Venturi ·798: Brunaci ·78; and finally, Michelotti the younger, in a very extensive and well conducted series of experiments with different series of orifices and heads of water determined a mean of ·787, but found the ratio to become less as the size of the orifice was diminished, and likewise as the head pressure was increased.

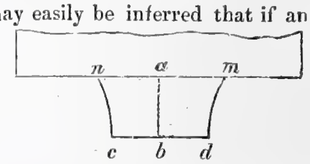
From these numbers it then appears that the area of the section of the contracted vein may be taken in practice as $\frac{5}{8}$ths of that of the orifice: in this we assume the diameter at ·7906, whereas the mean of the numbers above stated is ·793, a difference not greater than is due to inaccuracy of observation. Hence the quantity of water discharged in a second through such orifices as those we have had in view will be determined by the formula

$$Q = \frac{5 \times S \times \sqrt{2gh}}{8} = 5 \cdot 0156\ S \sqrt{h}$$

in which S expresses the area of the orifice in parts of a square foot, and Q the quantity of water in a cubic foot per second.

The same cause which renders the amount of contraction to a certain extent indefinite, also modifies the length of the external conoid; but the best conducted experiments, namely, those of Michelotti the younger, give the point of greatest contraction of the vein at a distance from the orifice equal to its radius; consequently Newton ought to have found, in the experiment above described, the smallest section of the vein to be $\frac{5}{16}$ths of an inch distant from the orifice instead of half an inch.

From these remarks it may easily be inferred that if an ajutage be attached outside of the orifice, of the form which the stream naturally takes, that is, having its lesser diameter *cd* equal to ·787 of its greater diameter *nm*, and its length *ab* equal to the radius *na*, that the discharge will not be diminished and that the velocity of escape will be that due to the head of water in the vessel *less* the small fraction expended in overcoming the cohesive attraction of the effluent particles. This is almost exactly what takes place, and accordingly with such an ajutage we obtain very nearly the full discharge due to the pressure; that is,



$$Q = S \sqrt{2gh}$$

in which the literal quantities have the same values as before. Having premised these circumstances, we are in a condition to understand the following proposition first announced by Daniel Bernoulli, in his Hydrodynamics (p. 278).

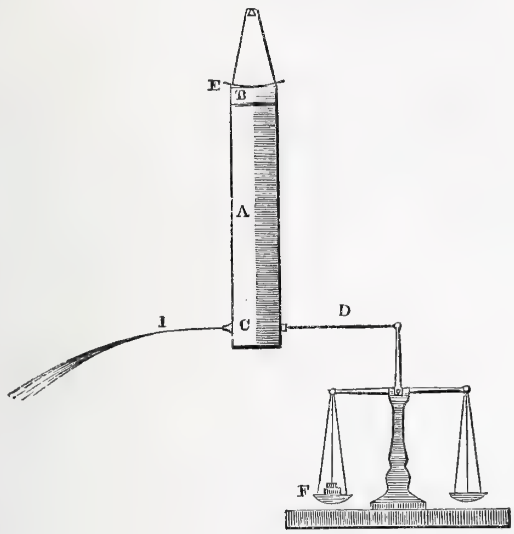
" If a jet of water issue from the side of a vessel with the velocity which a body would acquire in falling freely from the surface to the depth of the orifice, the repulsion of the effluent water in the opposite direction to the jet will be equal to the weight of a column of water, of which the base is equal to the section of the contracted vein, and the height equal to twice the depth of the water over the orifice."

Newton, in the first edition of the Principia made the reaction equal to the weight of a column of water of which the base was the area of the orifice, and the height equal to that of the water above the same; but in the third edition we find this corrected in the following terms:—" And the force with which the whole motion of the effluent water may be generated is equal to the weight of a cylindrical column of water whose base is the section of the contracted vein, and whose altitude is equal to twice the depth of the water in the vessel. For the effluent water, in the time it becomes equal to the column, may acquire by falling by its own weight from the height of the water in the vessel, a velocity equal to that with which it escapes." (Prop. 36. Cor. 2.)

* Newton seems here to refer to experiments other than his own; but we have met with no account of investigations anterior to those made and described by himself.

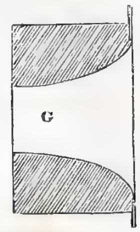
He also suggested a method by which the re-action might be easily measured, and which was adopted by the late Mr Peter Ewart, in an elaborate series of experiments on the Measure Moving Force, published in the Memoirs of the Manchester Philosophical Society (vol. II.), from which we borrow the following description:—

After stating that the vessel E was suspended like a pendulum, as had previously been done by Sir Isaac Newton in his experiments, he informs us that in order to ascertain the reaction as accurately as possible, he made use of a balance-beam furnished with a perpendicular arm of the same length as the horizontal arms as represented in the annexed figure.



The scales were exactly balanced, and the end of the rod D made just to touch the side of the vessel. The orifice was then opened and the water in the vessel was kept uniformly at the same height, a stream falling gently on the plate E. The scale F, having been raised by the re-action of the jet, weights were put into it till it was brought exactly to the position in which it was before the orifice was opened. The diameter of the vessel was 7 inches, and the height BC exactly 3 feet. He tried orifices of various diameters, from ·35 to ·7 of an inch, and their exact diameters were ascertained by a micrometer, and the time carefully observed in which 30 lbs. of water were discharged through each orifice.

When the orifice was made in a thin plate of $\frac{1}{30}$th of an inch in thickness, he found the reaction to be greater than Sir Isaac Newton's first conclusion in the ratio of 1·14 to 1. There were some variations in the results of the experiments, but the greatest reaction, was as 1·16 to 1, and the least is 1·09 to 1, which fall far short of Sir Isaac Newton's last inference. The velocity of the water at the orifice (ascertained by observing the time in which 30 lbs. was discharged) was less than that which a body would acquire in falling freely from B to C, in the ratio of ·6 to 1. He found no constant ratio to subsist between the diameter of the contracted vein and that of the orifice; and observing a considerable opacity in the jet at the contracted vein, he concluded it to be divided into a number of different filaments, and gave up all hopes of ascertaining the actual area of the section of the stream at that place by measuring its diameter. But after repeated trials he found that when the water issued through a contracted hole of the shape represented in the annexed figure, the jet was quite transparent, and the reaction (taking the mean of 12 experiments with four different orifices), was less than the weight of a column of water of twice the height of the head (B C) and diameter of the smallest part of the whole, in the ratio of ·865 to 1. The least reaction was as ·85 to 1, and the greatest ·88 to 1. By measuring the quantity of water delivered in a given time, he found the velocity of the jet, at the smallest part of the orifice, to be less than that which a body would acquire in falling freely from B to C in the ratio of ·94 to 1.



The inference respecting the velocity of effluence here drawn from the quantity of water discharged in a given time, being less than that due to the size of the orifice, is by no means conclusive: the fact, indeed, seems rather to show that the form of the adjutage deviated to some extent from that of the contracted vein, and, accordingly, that a partial contraction of the jet took place, beyond the adjutage, to the extent of ·06 of the area. Taking, therefore, the mean ratio of reaction at ·865 to 1, as stated in reference to the least area of the adjutage, we find that the reaction measured by the actual discharge must have been equal to a column of 1·96 times the height of B C, that is, ·98 of twice that head; or expressed otherwise, equal to $2BC \times ·02BC$; so that taking the height B C at three feet, as stated above, the amount of reaction would be equivalent to the weight of a column of water, whose base was the least area of the jet, and height 5 feet $10\frac{1}{2}$ inches.

After some remarks on Newton's conclusion, the author proceeds—" If we suppose the velocity of the jet to be equal to that which is due to the head, and the vessel to move uniformly in the opposite direction, C D, with the same velocity, the water will be at rest as it issues. Let a represent the area of the smallest section of the orifice; then, while the vessel has moved through a space $= 2$ BC, a quantity of water represented by $a \times 2$ BC has descended from B to C, and been brought to rest. But the reaction is $= a \times 2$ BC, and this multiplied by 2 BC, the space through which it has acted gives $a \times (2\text{ BC})^2$ for the amount of the moving (labouring) force produced, which is exactly the quantity of moving (labouring) force necessary to raise the column $a \times 2$ BC to the height of BC, and to project it with the velocity 2 BC. For a moving (labouring) force $= a \times 2$ BC $\times 2$ BC will raise that column from BC, and an equal moving (labouring) force will generate the velocity 2 BC in the same column; therefore $2a \times 2\text{ BC} \times \text{BC} = a \times (2\text{ BC})^2$ is the whole moving (labouring) force necessary to restore that column to the place and condition in which it was before it began to descend; and as no moving (labouring) force has been expanded in producing change of figure, that quantity of force must be found in the reaction of the water through the space which the vessel has moved, while the water descended and was brought to rest."

From this subject Mr. Ewart proceeds to investigate the principles of the reaction water-wheel, but like all his predecessors, loses his way in the problem at a few steps beyond the threshold. But this is a subject which we reserve for a lengthened discussion on a future occasion, simply observing in passing, that the reaction wheel, instead of realizing only from 30 to 45 per cent. of the effect of the water, as some *calculators* have attempted to prove, has been found experimentally to yield 80 per cent. of the power of the water, that is, 80 per cent. of working effect; and calculation shows that its real effect, exclusive of the friction of its journals, the resistance of the atmosphere and absorption of power by the passage of the water through the supply pipe, is upwards of 84 per cent.

The explanation given by Mr Ewart of the amount of reaction, measured by the pressure of a column of water, although accurate in principle, is nevertheless involved by considerations altogether apart from the simple fact that a column of effluent water is capable of balancing a column of still water of double the height. To arrive at the simplest form of explanation, let us in the first place understand precisely what is meant by the reaction of water, and here it is necessary to keep in view the universally recognised principle in hydrostatics, that if water be confined in a

vessel, it presses upon it on all sides equally in proportion to its depth. Now, taking the weight of a cubic foot of water at 62·3263 lbs, the pressure of one square inch of base, and 1 foot high, will be 0·43282 lb.; consequently if an aperture of that area be opened in the side of the containing vessel, which, referring to the figure illustrative of Mr Ewart's experiments, may be supposed to be 3 feet deep above the centre of the aperture, there will be removed from that side of the vessel a pressure equal to (0·43282 × 3) lbs, and consequently the vessel will tend to move in the opposite direction, and necessarily with double that pressure, as will presently appear. This tendency to motion in the opposite direction to that in which the water issues is what is termed the *reaction* of the water; it is simply the unbalanced pressure arising from the surface acted upon being so much less on the one side than on the other.

Now, the reason why we have a reacting pressure equal to double the height of the column, becomes immediately obvious from the well-known law in physics, that a body uniformly accelerated in falling by the force of gravity, would describe double the space through which it has fallen, by the final velocity, in the same unit of time, should that velocity become uniform. Let us, in the first place, suppose for the sake of keeping by generally known and understood terms, that the depth of the water in the vessel from the surface to the centre of the orifice is 16·1 feet. Now a heavy body falling freely would, during one second of time descend through that height, and being uniformly accelerated, would attain, at the end of its descent, a velocity which, becoming uniform, would carry it through twice 16·1 feet = 32·2 feet in the succeeding second of time. But the water issues through the orifice with a velocity (assumed to be) equal to that which a body will acquire in falling freely from the height of the surface to the level of the axis of the jet; it is therefore manifest that under an effluent velocity of 32·2 feet per second, a column of water equal to double the depth (16·1 × 2), or of equal depth, and of double area of base, must have been ejected during one second; but the pressure of reaction being necessarily measured by the weight of the reacting column, the pressure developed during the time of efflux must be capable of balancing an equal column of the fluid in a state of rest, that is a column equivalent to twice the virtual head. This is further obvious from the fact that a column of that magnitude will contain exactly the same number of particles as are brought into action by the efflux of the fluid during every instant of time; and the pressure of reaction of every particle of the effluent column must be equal to the pressure of gravity (that is the weight) of every particle of the statical column. And for this last we may manifestly substitute its equivalent of weight in a beam balance, as was done by Mr Ewart.

For other depths than 16·1 feet, the explanation is equally simple, except that the element of time becomes greater or less than the unit of one second. Thus, reverting to Mr. Ewart's experiments, the vessel being 3 feet deep, the velocity of efflux will be $\sqrt{6{\cdot}44 \times 3} = 13{\cdot}9$ feet per second; and the time t in which a body falling freely would pass through 3 feet would be from the well-known formula

$$t = \frac{2h}{v} = \frac{6}{13{\cdot}9} = {\cdot}4317 \text{ second.}$$

Now the space through which a body falling freely under the influence of gravity in the time t is $\frac{v^2}{2g} = \frac{1}{2}\,t\,v$ since $v = gt$; consequently the space through which it would move with the first velocity, according to the proposition above announced, would be $\frac{1}{2}\,t\,v \times 2 = t\,v$; and the velocity of the water of the jet corresponding to that of a heavy body falling freely from the surface, we have as the discharge, measured in terms of the column of water of the same area as the jet, a height expressed by

$$t\,v = {\cdot}4317 \times 13{\cdot}9 = 6 \text{ feet,}$$

which measures the reacting pressure theoretically, and as we have seen, the theoretical pressure differs very little from the experimental result, the least area of the jet being taken as the base of the reacting column.

The same principle explains the resistance of a fluid to a body moving through it: the relative motions are nearly the same as in the impulse of the jet, which issuing with a velocity varying as the square root of the height, we have only to consider the case reversed, and we find the height of the column of pressure varying as the square of the velocity. But the resistance to the body moving in the fluid may be generally expressed in terms of a column of the fluid projected against it, and which will vary as the square of the velocity of the moving body.

GLACIERS AND GLACIAL PHENOMENA.

The attention of philosophers has been much directed of late years, to the subject of those accumulations of ice and snow, on the higher mountains of Europe, which the Germans denominate Gletscher, and we Glaciers. Since Saussure and Scheuchzer first broke ground on this subject, several inquirers have made farther investigations, amongst the most eminent of whom are Charpentier, Agassiz, Ebel, Hugi, and our countryman, Dr Forbes of Edinburgh.

As the geographical relations of the Alpine ranges became better known, some persons employed themselves in climbing with vast pains to the ice clad summits of peaks where human foot had never trod, whilst others sought to penetrate into the secret operations of that glacier world. But nature seemed as if she sported with those adventurous persons who dared to pry into her mysterious ongoings, and a long time elapsed before it could be said with any certainty that the laws were known, which governed the motions of the glaciers. It was reserved to the untiring assiduity of Dr. Forbes, who pursued his inquiries in the true spirit of the inductive philosophers, to unfold the process by which the glaciers moved from their cradles of rock into the valleys below. There were two principal hypotheses on this subject; that of Saussure, and that of Scheuchzer. The former supposed that the pressure of the upper part of the glacier and its own weight caused the lower part to advance; the latter that the water which was continually produced upon the surface by the sun's heat passed downwards, and was insinuated into the crevices that traversed the mass in every direction, where it froze again and exerted a mighty force in expanding the glacier. Of course that force was exhibited principally where there was least resistance, namely, vertically upwards, or in the direction of the slope. Adherents to these rival hypotheses were not wanting to support them; but there were many difficulties in the way of unprejudiced persons acknowledging the truth of either. Neither satisfied the mind of Dr Forbes, who betook himself to the Alps themselves, where he might personally examine the very phenomena which ought to decide the question. He explored the innermost recesses of the glaciers, and devoted a considerable time to the study of the facts appertaining to their origin and progression. He crossed the Alps twenty-seven times by twenty-three several passes, traversing immense beds of snow and ice, which few people had ever even seen previously. The result of his minute examination led him to announce another hypothesis which we have no doubt is the true one, namely, that a glacier is not a mass of solid ice, but a compound of ice and water, more or less yielding according to its state of wetness or infiltration; that in summer it is saturated to a great depth by water which even in winter only partially freezes, and that the viscous body thus produced, is urged down slopes of a certain inclination by a mutual pressure of the parts. That a glacier really possesses a much greater fluidity than at first sight appears probable, is shown from the facts that a piece of glacier ice

when much saturated by water has a flexibility sensible to the hand, and that when a glacier has obtained a passage through a narrow gorge into a wide valley it spreads itself out, and will again contract itself to pass through a narrow opening. It further appears that the centre of the surface of a glacier moves more rapidly than the sides, just like a stream of water, because there is less friction in the middle than elsewhere; and that a glacier has also like a stream, its still pools and its rapids, for when embayed by rocks, it accumulates and its velocity decreases; when issuing through a narrow passage its velocity increases.

Glaciers are usually classed according to the form given to them by the bed in which they rest. The *canal-shaped* glacier is seen in the Miage glacier near Commayeur, of which Basil Hall says, that he is acquainted with only one other scene in the world which can pretend to rival it in natural magnificence, namely, Niagara. The Mer de glace is another example, and others are to be seen in the glaciers of Zermatt, Viesch, Aletsch, and the Aar. The *oval-shaped* glacier may be seen in that of the Rhone, a frequent object of visit, and that of La Brenva described by Professor Forbes, is of this form. The *basin-shaped* glacier lies in a circular hollow of the mountain, and only sends a very small arm through a narrow aperture into the valley. The Taléfre glacier is an example, of which the width of the arm is only a seventh of the diameter of the body. Glaciers of the *second class* are very numerous; they are found between the rocks in the higher parts of the Alps unconnected with the great glaciers which protrude themselves below the snow line.

Professor Forbes states the following facts respecting the construction and motion of glaciers :—1. The motion of the ice-sea during summer and autumn in some places amounts to four feet in 24 hours, in other places to only eight or nine inches. 2. The advance is continuous. 3. The rate increases with the angle of inclination. 4. The motion is influenced by the state of the weather, and although it is much less in winter yet it never ceases. 5. The greatest variations in the motion are at the sides, the advance being more uniform in the middle.

To the remarkable and puzzling phenomena of glaciers, belong the changes which they sometimes undergo in their edges and surface, any attempt to explain which by actual observation is attended with difficulty and danger. In the 15th and 16th centuries there were several Alpine passes which were traversable, but are now extremely dangerous. Of these we may enumerate the glacier between Aletsch and Grindelwald, that between Brieg and Grindelwald, that between Saas and Anzasca over the Monte Moro, that between Zermatt and Evolena over the Col d' Erin, and that between Chamouni and Courmayeur over the Col-du-Géant. There is reason to believe that many glaciers had in former years a greater extent than they have now. The immense lines of rock and stone called *Moraines*, which lie at the termination of a glacier, are now found in some instances at the distance of a mile or more from its present extremity. If we adopt the opinion which at once suggests itself, namely, that the dimensions of the glacier are less than in former times, it is difficult to avoid concluding that the glacier has extended right through the whole valley, when we see a similar moraine at its mouth; and such a view is confirmed by the appearances which in the neighbourhood of such a moraine the soil and surface of the valley present—the rocks are furrowed, and bear scratches in the direction of a moving glacier; others are rounded in their forms, and have polished surfaces. These appearances may be seen at St. Servoz, whither the granite of Mont Blanc has been carried in blocks and sand, and can be traced for many miles.

Professor Forbes has described with great minuteness the interior structure of a glacier, and he appeals to the phenomena brought to light in confirmation of his opinions. It is stated by him to consist of an alternation of bands marked by blue and greenish-blue or white curves which traverse the ice throughout its entire thickness whenever and wherever a section is made. In the glacier where he first discovered this structure, he says that the stratification exhibited an appearance of almost vertical layers nearly parallel to the length of the glaciers, inclining outwards a little like the rays of a fan, as it approached either shore. In the glacier of the Brenva, he found this confirmation more beautifully displayed than in any other. This structure, he asserts, is as peculiar to the glacier as the veins of woody fibre are to a piece of mahogany. The blue veins are hardest because formed of compact unperforated ice, whilst the white portion is full of small cavities disseminated throughout and communicating with one another. Looking through a piece of ice cut from its bed, it seems opaque unless we look parallel to the veins. Some cause not yet clearly explained, occasions the alternation of the porous veins at certain intervals along the glacier. The particles of earth and sand which the winds and water spread over the entire breadth of the ice, find a lodgement in those portions of the glacier, where the ice is most porous, and singular hyperbolic brownish bands are to be noticed in the surface, which mark the porous veined structure. The bands are called dirt-bands, by the Professor. These lines of discolouration are seen with difficulty when near at hand, except under a peculiar light. In broad daylight without clouds, only the most conspicuous ones could be seen, but standing on an elevated station as many as eighteen could be counted, having an average interval of 711 feet.

It has sometimes been conjectured that the line of perpetual snow, or as it is frequently called, the line of perpetual congelation, described a regular curve on the surface of the earth, but there have been too few observations made as yet to authorize us to say with certainty what shape the line takes. We know however that as it approaches the poles, its height decreases, and in summer it is higher than in winter. In the Cordilleras it is about 18,300 feet high, in the Alps it sinks to 8900 feet, and in Norway under the 71° of latitude to 2406 feet. The mass of snow on a mountain bears no relation to its height. The summit of Chimborazo, which for a long while was deemed the highest mountain in the world, is only 600 feet above the snow line, whilst between 6000 and 7000 feet of Mont Blanc, a far inferior mountain, is perpetually wrapt in snow. The Himalaya, of whose storied peaks, attaining an altitude of 25,000 feet, we only learnt for the first time of late years, passes beyond the snow line on its southern slope by 9000 feet, but on its northern side by 12,000 feet. The mountain Erebus, discovered by James Ross in 1841, within 15° of the Pole, rising 12,000 feet above the frozen coast of the Antartic ocean, affords a singular spectacle since, whilst its sides are white, it pours out continually fiery streams from its volcano upon the icy masses of a silent desert. The volcano Mouna-Roa in Owyhee, under the 70° of latitude, although 15,000 feet high, does not reach the limit of perpetual snow. The ascent of a lofty mountain between the tropics must afford great interest to an observer of nature. The labour of a few days takes him, as if by magic, through every variety of climate which, if he kept moving horizontally, he could only experience by a tedious journey of many months. From palm forests he passes along to the region of chesnut trees and vines; he next finds himself amongst oaks and beeches, which are changed in time for birches, that give way to the persevering pine, and then he emerges upon a country which is sparingly covered by grass and lichen. If he pursues his course upwards, his steps have to contend with the impediment of snow and ice.

Geographical distribution of Glaciers. Asia.—Notwithstanding the enormous masses of snow on the Himalaya and the Andes, it

appears that no glaciers are known upon those mountain ranges. This is certainly the case in the southern continent of America, and Alexander Von Humboldt ascribes their absence to the extraordinary steepness of the mountain-sides, and the exceeding dryness of the atmosphere in those countries, which prevents the accumulation of water on them. The changes in the temperature are very slight, and exert little influence on the snow. In the Himalaya, where the snow fields are very extensive and feed a great number of streams, the absence of glaciers is somewhat surprising. The source of the Ganges is in a semi-circular hollow of considerable extent, shut in by five peaks, and filled with snow that never disappears. However, there are glaciers further north in the mountains that bound Chinese Tartary, and in the mountains of Roucorlun. In Little Tibet, not far from Arindo, under a latitude of 35° 40′, there is a remarkable glacier. Glaciers are not common in Altai. Captain Hall described the Katuni-glacier very minutely; it is on the declivity of the Bjeludia hills (11,000 feet high), in Russia Altai, and is a mile and a half long. We have not heard of glaciers in the Caucasus or in the Ural mountain. *Europe*—Glaciers are finely developed in the great Alpine chain, whilst in the Pyrenees, although elevating themselves above the snow line, only poor specimens are to be found. The principal groups of glaciers in the Alps, are 1. Mont Pelous; 2. Mont Iseran, 3. Mont Blanc; 4. Mont Velan; 5. Monte Rosa; 6. The Bernese Oberland; 7. St. Gothard; 8. St. Bernard; 9. The Bernina; 10. The Ortler Spitz and the Oetzthal; 11. The Venediger, and the Grosse Glockner. There are numerous glaciers in Norway under the latitudes of 61° and 62°. The interior of Iceland is covered with them, the principal ones being those of the Swinafells-Iskull, and Holaar-Iskull. The glaciers of Spitzbergen are of great interest on account of their northern situation, since they probably touch the point where the snow line is at the level of the sea. The floating icebergs which are plentiful in Baffin's bay, and render navigation dangerous, are caused by the destruction of masses of frozen water by the waves. *South America.*—In the southern hemisphere glaciers are first found on the west coast of Patagonia, and extend to the sea under latitude 46° 40′. They are plentiful in Terra del Fuego. Darwin has given an excellent description of them.

It has been calculated that the glaciers of the European Alps are above 400 in number and cover about 1400 square miles. From them many important streams take their rise, especially on the north. The Rhine and the Rhone have severally their source in glaciers which bear their name. The glaciers of Mont Blanc and the Finsteraarhorn, (Bernese Oberland), are the most considerable groups. The culminating point of the first is Mont Blanc. himself the highest European mountain, being 15744 feet above the sea. Its top is saddle-shaped and bears the name of the Ass's Back. The southern side of this hill is extremely steep, and when seen from the Alleé Blanche, looks like a perpendicular precipice. Several large glaciers descend its flanks, and amongst them is the celebrated Mer de Glace. From its lower extremity the Arveron issues about two miles from Chamouni. Professor Forbes counted thirty-four glaciers altogether on Mont Blanc. The Bernese group has also enormous fields of ice, the chief ones being those on the sides of the Finsteraarhorn, the Breithorn, the Schreckhorn, the Jungfrau, and the Wetterhorn. Altogether there are twenty-five glaciers on this group of which seven descend into the much visited valley of Lauterbrunen.

THE THEORY OF DEW.

Few natural phenomena have met with such close investigation, or have been connected with so many antagonistic theories, as the formation of dew. Wells was the first to prove by direct experiment that it is not a gaseous production of the earth, as the old theory hath it, nor yet a deposit of the sky, but that it results from the condensation of the elastic and invisible vapour which surrounds all bodies, by their calorific radiation towards a clear sky. According to this hypothesis, vegetable formations, wood, glass, varnish and lamp black, receive a deposit of dew, from their great radiation of heat under a clear sky, while metals repel it, by reason of their slight loss of heat from the same cause.

This theory of radiation was long ago started amongst engineers, and it has often been proposed to polish all metallic surfaces, along which heat was merely conveyed, without the intention of thence distributing it. However conclusive this may appear, as relating to the theory of dew, there have not been wanting numbers to put forward totally opposite ideas. Saussure and Benedict Prevost both held to the supposition that electricity was the cause of the absence of dew on metals.

Leslie attributed it to a particular repulsion which metallic surfaces exert against aqueous vapour, and the propagators of the theory of the rising dew give as a reason for it, the heat and electricity disengaged in the chemical action which metals exert upon the molecules of the vapour at the instant of their change to the liquid state. M. Melloni, in a letter to Arago, mentions the following experiments which disprove these theories. "I first took three thermometers graduated on the stalk; I then passed each tube through a cork stopper, and fixed it at 5 or 6 millimetres from the bulb. This stopper served as a point of support to two parts of the metallic apparatus, in which I enclosed my thermometers intended for experiments on nocturnal cold. The first is a small vessel of silver or copper, very thin, resembling a thimble, and having its surface smooth and polished, and of sufficient size to contain the bulb of the instrument. The second is composed of a cylinder of tin, closed at one extremity and open at the other, forming an envelope to a graduated tube. These two metallic pieces (which can be taken off and put on with the greatest ease) are easily kept in their place by the pressure and elasticity of the cork.

Now, imagine three wide recipients of tin, having a lateral opening by which we may introduce, close to the bottom, the armed bulbs of three thermometers, leaving their stalks and envelope disposed horizontally on the outside; imagine these recipients supported by slender tubes of metal, provided with covers of the same substance, the whole exposed to the free air in a calm clear night; and remembering that one of the thermometer's armature is blackened, the two others in their natural state, and the recipients sometimes open and sometimes closed,—you will have an idea of the experiments I instituted to compare the nocturnal radiation of silver with that of *lamp-black.* Let us suppose the recipients to be first closed; our three thermometers then indicate the same temperature. Let us then leave one of the vessels containing the metallic thermometers closed, and open the two others. Very delicate instruments and very minute comparisons are requisite to observe and measure the extremely slight sinking produced in the metallic thermometer exposed to the sky; but the blackened one will visibly sink, and, after some minutes, will indicate three or four degrees less than the thermometer in the closed vessel,—an evident proof that this difference is owing to the calorific radiation which the blackened apparatus vibrates to the sky, and not at all to the contact of the external air, which takes place equally on it and on the polished metal apparatus of the other exposed thermometer."

These results have fully confirmed the fact lately announced to the Academy of Sciences by M. M. Provostaye and Desains, that the emissive power of metals is far less than has been hitherto understood from the experiments of Leslie, Dulong, and Petit. Thus, if the radiation of lamp-black is taken at 100, then that of luminated silver would stand at 3.026. M. M. de la Provostaye and Desains found 5.37 for silver chemically precipitated upon copper, and 2·10 when the same coating was burnished. From observations made so long ago as 1838, M. Melloni is inclined to believe that the differences of radiating force manifested in Leslie's celebrated experiment on the rough and polished faces of a cube, does not arise as is generally understood, from the presence of grooves in the metal, but from a change in the density resulting from the operation, and adduces the following facts in support of his conclusions :—1. The variations of emissive power produced by grooves does not appear much except in the metals; marble, jet, and ivory, grooved or polished, always radiate with the same energy. 3. Silver melted, and cooled slowly in moulds of sand, polished with oil and charcoal, and then grooved with a diamond in such a manner as to compress and condense the bottom of the rays, diminishes instead of augmenting its radiating force in pas-

sing from the polished to the rough state. 3. This same kind of melted and polished silver becomes less radiating when beaten on an anvil, or passed under the *laminoir.*

It will be seen, then, that the results are identical with those of the experiments of M. M. Provostaye and Desains, for silver precipitated chemically on copper, is much less dense than laminated silver, and the latter is again of inferior density to burnished silver.

Thermoscopic apparatus, as used by M. Melloni, and having the protecting armatures covered with varnish, plumbago, glue, sawdust, sand, earth, and leaves of plants, have invariably indicated a decrease in temperature previous to becoming moistened with dew, and in no instance have the armatures, when polished, received a deposition of dew, even in humid nights, unless there were traces of mist in the atmosphere.

To the same experimenter we owe the following tests, which he considers to completely substantiate Wells's hypothesis :—

On a disc of tin, of a single piece, as broad and thin as possible, I traced a concentric circle, of a radius equal to one-third of that of the disc, and covered it with a thick coat of varnish. I then cut another sheet of tinned iron, a second disc of 10 millimetres narrower than the varnished circle ; and having soldered to its centre, and perpendicularly to its surface, the extremity of a wire 2 millimetres thick, and from 2 to 3 decimetres long, terminating in a point at the free extremity ; I perforated the large disc with a small central opening, and introduced the wire into it on the side of the varnished surface. The moveable piece was then pushed along this wire till its distance from the small disc was reduced to about 5 millimetres ; it was then fixed in this position by means of some drops of solder.

The two plates, thus united into a single system, are conveyed in the evening to the middle of the fields and left for a few minutes to themselves in a horizontal position, and far from the contact of any other body. If the night be calm and clear, we then easily and distinctly see dew produced on the surface of the large disc.

It is sufficient, indeed, to remember that in the position we are supposing the two discs to occupy, the smallest is uppermost, and as its radius is 5 millimetres less than the varnished circle of the large inferior disc, it follows that an annular band of this circle, 5 millimetres broad, will stand out around the vertical projection of the roof formed over it by the small metallic disc above. It is clear that this band will radiate towards the sky, will diminish its temperature, and become covered with dew, and will by degrees propagate the cold and dew consecutively from the side to the centre, and from the side to the circumference. The propagation, however, will go much further in the latter case, for the points cooled by communication will become cold by radiation when they are covered with dew, while the varnished points placed under the small disc cannot well be cooled but by contact. The central part of the varnished circle continues always dry, and the metallic zone which surrounds it is moistened to the edge, if the atmosphere be excessively humid.

Something paradoxical, however, here occurs, the same appearances are reproduced on the surface of the disc turned towards the ground. The dewy deposition primarily shows itself on the surface in the points opposite to the exterior annular band of varnish, and a slight whitish circle suddenly appears on the obscure field of the polished metal.

This circle gradually increases and sometimes approaches the edge, although it never extends to the central part, which remains perfectly dry and brilliant.

Thus we arrive at the irresistible conclusion that dew does not fall from the sky, for the upper disc is always dry, while the lower portion of the lesser one is moistened. Again, it does not rise from the ground, for when the lower surface of the large disc is bedewed, there is always a dry space in the centre. The first trace of the dew on the band covered with varnish, and its gradual communication with the adjacent and opposite portions of the great disc, when considered in relation to the sinking of the temperature, remarked in the varnished apparatus of the thermometers exposed to the air, proves to us that the production of dew, is alone a consequence of nocturnal radiation, communicating to bodies of great emissive power, sufficient cold for the condensation of the invisible vapour mingled with the atmosphere.

Unquestionably correct, as this theory appears to be, so far as the fundamental origin of dew is concerned, it is yet an acknowledged fact that an immense number of thermometrical and hygrometrical phenomena occur under cover of night, with a clear sky, which our present information cannot explain.

In order to attempt to disprove the principles of the theory founded on the different radiating powers of various substances, Wells' opponents exposed a number of similar thermometers prepared in various ways, to the action of the atmosphere during a calm summer's evening. By way of effecting a change in the surface of these instruments, they were each coated with some extraneous matter, as varnish, lamp-black, china ink. Others again were gilt, silverized, covered with vegetable matter, with pewter, and copper.

The primary observations of these instruments, thus treated and exposed, gave as a result, a series of slightly different temperatures ; but a subsequent examination shewed them to be all agreed in their indications. This test was then applied in a slightly different manner. A series of glass cylinders were planted in the ground, each having attached at its lower extremity, horizontal plates of zinc, copper, and glass. A recess was made in each plate for the reception of the bulb of a thermometer ; the tube, supported by an attaching wire, standing vertically upward ; a thermometer, intended to indicate the temperature being freely suspended between the plates. The results here obtained, coincided exactly with those of the former trial, as without regard to any calorific variations at the earliest period of exposure, each and all finally stood at one point,

According to the words of the experimenters then "the pretended nocturnal cold of bodies, indispensable to the formation of dew, was a mere chimera."

M. Melloni, in a second communication to Arago, shews the inference deduced from these tests, to be totally opposed to the realities of the case, and observes,—

"All the tubes of the thermometers were uncovered, and, in the last mentioned experiment, the bulbs of the thermometer communicated through the intermediate plates, with the cylinders which supported the apparatus. Now the glass of which these tubes and cylinders were composed, radiates considerably, its temperature sinks, and the cold thus acquired is communicated to the bodies that touch it : the latter being placed in a very humid air, then precipitate the aqueous vapour ; but we know that water radiates and cools with as much energy as glass, varnish, and *lamp-black.* It was, therefore, nothing surprising that the thermometers in contact with the plates or plateaux of metal indicated, after some time, the same temperature as the thermometer surrounded with the most radiating substances. From the circumstances of the metallic surfaces, which were found covered with dew, becoming as cold as the vitrified or blackened surfaces, it might well follow that the water, glass, and *lamp-black,* are bodies possessed of emissive powers sensibly equal ; but we could never be justified in inferring logically from this experiment, that metals cool, during calm and clear nights, as much as *lamp-black* and glass."

In order to arrive at the true state of matters, glass ought to be superseded by tubes of tin, which metal scarcely radiates at all, keeping the thermometer well insulated from the earth, and covering it at all parts with metal plates. These plates being polished, the thermometer indicates as near as may be, the actual temperature of the atmosphere, and when the covering is varnished, or blackened, we find the degree of cold produced by the radiation of this substance, as compared with the polished thermometer.

With instruments thus mounted, M. Melloni states that he has convinced himself that the leaves of plants, glass, varnish, and lamp-black, are always from 1 to 2 degrees below the temperature of the surrounding atmosphere. This is a very slight difference, as compared with Wilson and Wells' experiments, which state it to be 7 or 8 degrees lower. In their trials however, the thermometers were raised above the surface of the earth, a height of between three and four feet, while the test instruments were close to the ground.

According to Pictets' experiments, the temperature of the air decreases excessively on calm and still clear nights, as we approach

the earth, and to this, we must ascribe a great portion of the discrepancy pointed out. In one of Wells' trials, a thermometer wrapped round with loose wool, when placed at the same level as a free thermometer, gave a lowering temperature of 50°3. This being so extraordinarily great, Melloni undertook the investigation of the point, and decided that the superior nocturnal refrigeration of the fibrous matter, as cotton or wool, over lamp-black, was to be attributed to a modification in their emissive power arising from the presence of air in the interstices of the fibres, Our Polar travellers have long ago informed us that the nocturnal cold of bodies does not vary with the temperature of the atmosphere. Parry and Scoresby found that during calm nights, the snow in the polar regions cooled about 9° below a stratum of air, raised from three to four feet, both when the atmosphere was from 25° or 30°, and when it was 0°. Melloni intends shortly to present to the Neapolitan Academy of Sciences, a memoir, detailing the whole of his experiences in this wide field of discovery, which lead him to comprehend fully the following phenomena :—

"The distribution of temperature among grass, which is found to be colder in the night among it than at the surface of the meadow. 2d. The inversion of the ordinary temperatures of the atmosphere under the earth's surface. 3d, The great humidity of the air near plants, from the first instant that the dew begins to appear. 4th, The injurious action of the least breath of wind. 5th, The formation and accumulation of dew during the whole course of the night. 6th, Its successive propagation from below, upwards. 7th, The small quantity of dew on trees when compared with grass and low field plants. 8th, The disappearance of small drops of dew, which sometimes takes place on the lower parts of plants, while they are forming on the upper parts. 9th, The variable proportion of the meteor in the different seasons of the year. 10th, Its general distribution over the surface of the globe. 11th, The great difference between the diurnal and nocturnal temperatures of the torrid zone. 12th, The absence of dew in the small islands of Polynesia, and on vessels sailing in the midst of large seas. 13th, Its abundant formation when the vessels approach certain shores of continents. 14th, The sharp cold produced in the night in the sandy plains of central Africa. 15th, The natural artificial congelation of shallow waters, when the temperature of the atmosphere is from 5° to 6° above zero, by taking into account the indisputable fact that water does not cool more than 1°·5 in consequence of its direct radiation."

HISTORY.

CHAPTER XXIV.

REPRESENTATIVE GOVERNMENTS.

In last chapter, in which the state of continental Europe during the period from 1519 to 1788 was dwelt upon, we found every where the whole power vested in the hands of a few—the masses being almost devoid of recognised rights; mechanical art and science arrived at a high state of perfection—the theory of government, law, morals and religion skilfully and eagerly canvassed—every where a zealous theoretical admiration of what was good, just, and beautiful—the practice no where. The influential few enervated by self-indulgence, and reduced by their extravagance to the verge of beggary. The unprivileged, rude, and ignorant, sensible only to the insults and outrages offered to their helpless condition, glaring with wolfish eyes on the seeming happiness of their supposed more fortunate fellow-beings. An ingenious and restless class of adventurers, lay and clerical, political and literary, sprung from the dregs of society, living from hand to mouth, practising all sorts of quackeries in order to preserve a footing among the luxurious classes. The imbecile good asking how they could alleviate the wretchedness of the myriads, and arrest the impending destruction which they foreboded rather than saw; their moral and political quack doctors gulling them with all sorts of flattering tales. This was the state of continental Europe during the third quarter of the eighteenth century—at which period the influence of the English race with its peculiar institutions came for the first time to be fully felt in Europe. To make this fully understood I must revert to the past.

The main ingredient in British history, from the middle of the fifth century of our era is Teutonic. Every where the Celtic race sunk into a subordinate position. It was driven back into the mountain lands of Wales and Scotland, and into Ireland. In course of time Wales and Ireland were subdued; and although Scotland maintained its independence, and was finally incorporated with the southern half of the island on a footing of equality, it was not as a Celtic state. The intermarriage of a Celtic sovereign with a Saxon princess about the time of the conquest, collected a number of Saxon and Norman refugees about the court, where their greater advance in civilisation soon gave them a preponderating influence. The importance of the provinces south of the Forth, peopled with a Teutonic race, and the interests of the great Norse families which had obtained a footing in the Hebrides, and here and there as far south as the Ochils on the main land, combined to establish their Saxon-Norman influence. The Celts maintained a brave struggle, but the blood of the royal race becoming more and more mixed with the Norman, they were left without a head, and, broken and disunited, forced to give way to the intruder. The population in the hill districts continues essentially Celtic to this day, but the forms of government and laws are Teutonic—the reigning race is of Teutonic origin.

It is difficult to say how much of the institutions of Romanised South Britain survived the Saxon invasion, to what amount a British population was incorporated into, and assimilated to, the conquering race. To judge by the remains of Saxon literature, the extirpation of the Britons within the territories of the Heptarchy was complete. Of this, however, it is allowable to doubt. So complete a destruction of the native settlers characterised the settlement of no other Teutonic race within the limits of the old Roman empire. The historical works we possess in Anglo-Saxon, are all of a date sufficiently recent to admit of much having been forgotten and distorted by oral tradition, between the time of their compilation and the first settlement of the Saxons and Angles; and in addition to these negative grounds in favour of the presumption, we have the fact that most of the towns which existed in Britain under the Romans have survived—that we find uninterrupted mention of them in every age, and that their names are still essentially the same as those they originally bore. It must be remembered, however, that Britain was the last province incorporated into the Roman empire, and that there, in consequence, Roman civilisation and Roman institutions had least time to harden into enduring form. Also, that Britain was situated on the uttermost verge of the Roman empire, and, as was then believed, on the extreme verge of the habitable world, and that in it consequently the minds of the inhabitants had been least developed by external commerce. In this manner we can account for the entire disappearance of Roman language and customs under the Saxon domination. But the municipal forms of government survived in the towns. They were preserved the more easily on account of their analogy with the old Teutonic *gau* or valley or district constitution. The *gau* constitution, too, naturally prevailed in the rural districts of England, more than in any other states erected by invading Teutonic tribes. It was among the Germans on the upper Rhine, and along the Danube, that their constant wars with the Romans had given the fullest developement to the organization of *fursten* and *deenstgefelge*—princes and followers,—out of which the feudal arrangements sprung. Britain on the other hand was invaded and settled on by tribes from the peninsula of Jutland, the coasts of Friesland, the inland of Germany stretching in the direction of the Weser and the Harz, and from the countries north of the Baltic. Among these tribes the feudal institutions never have been fairly developed even to the present day. In England, previous to the northern conquest, we can trace in the persons of Earl Godwin and his sons the first dawn of something like the primitive arrangement of princes and followers as described by Tacitus, but nothing like a feudal system. The district constitution had full time to develope itself between the first conquests of the Saxons and the invasion of William the Norman, and to attain a degree of strength and consistency that defied the power of either feudalism or monarchy to suppress.

The battle of Hastings transferred the supreme power from a Saxon to a Norman dynasty. Events had paved the way for rendering such a transference easy. The Teutonic provinces of Britain which were united under the sway of the Mercian sovereigns, had for a long time previous been accustomed to see the crown transferred alternately from a Danish to a Saxon race. A number of the most important offices at court had, under Edward the Confessor, been bestowed upon Normans. The mass of the population north of the Humber were of the same lineage with the Norman leaders; and, scattered throughout the rest of England,

were many of the people called Danes, more or less affied to him by descent. There was a strong party in England inimical to a Saxon if not exactly inclined to a Norman dynasty. This circumstance favoured the first usurpation of William, and the skill and valour of himself and his successors held it fast until the *prestige* of antiquity had sanctioned their claim to sovereignty. Down to the termination of the wars of the Roses, however, the kings of England were foreigners, ruling over a people with whom they had nothing in common. Their Norman leaders, endowed with broad and fertile lands, were skilfully distributed throughout England, as so many garrisons to assure the obedience of the country. All the power was in this feudal army and its sovereign or leader—the wars in France were carried on by them and for their purposes—Wales and Ireland were conquered by and for them. The wars of the Roses nearly exterminated this military caste. Upon the restoration of internal peace by the marriage of Henry with the heiress of York, a principle of self-defence obliged them to make common cause with the rest of the population; and even although Henry had not been politic or ambitious enough to seek to become a national sovereign instead of a mere head of a feudal anarchy, circumstances would have compelled his successor, at latest, to take that step.

The English nation, however, had advanced rapidly in power and importance during the period which elapsed between the accession of William I. and the accession of Henry VII. The bulk of the lands had remained in the possession of Saxons. The Saxon nobility long preserved themselves unmingled with the Normans, and being, by the preponderance of the latter, driven to make common cause with the free Saxons of all ranks, a prouder spirit of equality was diffused through the mass. The old arrangement of rural and urban municipalities or districts, that is, of shires and burghs, was preserved. The Scire-graf in the one, the heads of the corporation in the other, administered the local police, preserved the peace, and raised the hue and cry. Even the subdivision of the shires into hundreds, was preserved in many places. In the shires the justices, in the towns the curial, exercised an extensive jurisdiction. The county and burgh courts apportioned and settled the aids that were to be given to the crown. Out of this remnant of the municipalities of the empire, arose the modern English Parliament, not out of the Wittenagemote, which ceased with the Saxon dynasty. The Peers, the great feudatories of the empire—the military leaders, upon whose fidelity depended the king's power to carry his ambitious designs into execution, were his great council; they forced upon him their advice and co-operation in every department of government. The original object in calling together an assembly of burgesses and knights of the shire, delegated by their respective burgh and shires, was to obtain, by means of a common deliberation, a common rate of aids. But two circumstances contributed to extend the sphere of their functions. It became, on the one hand, customary for their constituents to send up petitions and representations of grievances, with directions to their representatives to proportion their liberality to the crown to the readiness with which the one were granted, and the other redressed. On the other hand, the monarch availed himself of these periodical conventions of representatives from every district of the kingdom, to announce to them what new laws or what modifications of old laws he had resolved upon in his council, to spread the knowledge of these measures in an age when the press was not, and when readers were a great rarity. It could not but often happen that these legal innovations would be viewed as grievances, and remonstrated against in next convention of the knights and burgesses. The constant wars in which the ambition of the English kings involved them, kept them constantly in need of money, and a campaign being in those ages a thing of one year, the assemblage of the Commons of England became annual also. The body of Franklins had been always of consequence, and they became more important as the extinction of many old Norman families rescued the squirearchy from their overshadowing influence. With the increase of commerce the burghs also rose in importance. Their petitions and representations of grievances, and their remonstrances against royal legislation, merged insensibly in the concession to them of a voice in legislating for the kingdom. So early as the controversies of the Lollards, we find the Commons of England assuming a bold tone in discussions of state. This body was always separate from, and entirely independent of, the Peers, although the latter, "the king's great council," may on some occasions have met with them. The king was sovereign, not only of England, but of Wales and Ireland, and nominally, at least, of France and Scotland. The Peers were peers of his empire; the Commons were only the Commons of England. The legislative and financial authority of the latter did not extend beyond the limits of England. The Peer might be called to his sovereign's councils in any part of his dominions.

The position of all parties was materially altered during the period which intervened between the accession of Henry VII. and the Revolution of 1688. The king had become, not the head of a feudal militia holding various kingdoms in obedience, but the king of England. The Peers had become the Peers of England alone, not of the empire. Their national character was confirmed by the Reformation, which rendered the spiritual Peers no longer members of the Romish, but of a special Anglican church. But the greatest change was in the position of the House of Commons, which was the representative of the people of England—the Sovereign and the Peers having become integrant members of that people by the cutting off of their foreign connexions. It was not to be expected that either party should feel the change at first: the Commons, how much they had gained in strength and importance, or the King and Peers, how much nearer they had been brought on a level with the people—the energies of the strongest slumber, when there is no motive to bring them forth. The Crown, enriched by Henry's plunder of the church, and kept rich by the economy of Elizabeth, did not press hard on the people. The threats of foreign invasion aroused both the national and the religious spirit of the people to rally round the royal standard. Men speak of the weakness of Parliament under Elizabeth: it was merely the repose of a strength which had no motive to sting it to action. Under James, when foreign enemies no longer enforced unanimity by the pressure from without, and when the weak and extravagant monarch became exorbitant in his demand for gold, as he made himself ridiculous by his mode of lavishing it, the Commons ran restive. And under Charles, when an attempt was made to evade their refusal of aids by demanding what they had not granted, the Commons put forth their full power. That power, however, was from of old: it consisted in their being the chosen of the people for the discharge of certain functions, and in the people having been accustomed from time immemorial to regard them as such. The contest between a single individual, even though he be a crowned monarch, and a united people, must ever be unavailing. The Peerage was as dust in the balance: their importance had gone by with the time when England was only one of many states, subject to their feudal authority, with the thinning of their ranks by civil wars, and with the filling up of the vacant places by court favourites, worthless as imbecile. The Commons of England were the might of England, and they proved it, for they struck down both the Peerage and the Crown in the struggle which ensued. And that they did not maintain the authority they had thus usurped, was owing entirely to crime and blunder of their own. They prolonged their own power for an indefinite period, without re-election. They thus secured themselves from the people, whose nominees they were, and in being whose nominees alone consisted their strength. They repudiated their only title to power, and with that mad act their power departed from them. What cared the people of England for a small coterie of self-elected rulers? Cromwell overthrew "the Rump," and Cromwell was an able administrator, but, like all great administrators—with the single exception of Washington—he wanted insight to discern that administration is not constitution. He projected the re-establishment of the elective parliament, and upon a better basis than before; but he was impatient of the impediments opposed by such a council to his own plans—he could act, but he could not argue. He continued therefore to rule alone; and his government emanating exclusively from his own mind, died with him. The Restoration brought with it no adjustment of the contending claims of King and Commons, and the consequence was the Revolution of 1688.

This revolution originated in, and was directed by the court—taking that word in its widest sense as embracing the whole diplomatic body, as well the faction that was out of power, and many of its members even banished the kingdom, as that which was in office. The nation was ripe for following professing patriots, not for moving itself. The consequence was, that the whole movement was moulded and directed by a *bureaucratie*, and assumed the form and led to results most favourable to their ends. The powers of the monarch were curtailed, but the powers of the people were neither extended nor confirmed. Three kings, who could not speak English, and a woman, in close succession, were excellent materials in the hands of the diplomatists. Ministers came to have not only the responsibility, but the essentials of administrative power. The sovereign was more dependent on his ministers than they on him. Even George III. the monarch perhaps of the strongest will that ever existed, could not shake off William Pitt. The secret of this power lay in the organization of the two houses of Parliament. The changes of time had thrown many once populous electoral districts

entirely into the hands of wealthy individuals, and had divided the preponderating influence in others between a few. By the privilege of making Peers, a minister could strengthen himself in the upper house; by securing the friendship of a few burgh proprietors, he could strengthen himself in the lower. The peer looked upon the king, shorn as he was of many privileges, as only the first of the nobility. Their ambition took a bolder flight. England was in the hands of an oligarchy which, as is uniformly the case, divided into two factions, each invoking the aid of what remained of popular franchise, when it found itself in the ascendancy. The peculiar nature of our financial system lent facilities to corruption; the constitution of Parliament narrowed the field within which it was necessary to use it; and the self-enacted prolongation of the periods of Parliamentary election rendered the occasions for its exercise of less frequent recurrence. Under these forms an oligarchy governed England, and, secure of its parliament, sought to extend its legislative, financial, and administrative authority over all the dependencies of the empire.

Meanwhile, an English population had been growing up in America, subject to the crown of England and united to the state. In all these colonies the old English practice of vesting the police authority in local elective officers had been introduced. In all of them the old English prerogative of taxing themselves by their own representatives had been established; and to these representatives had been entrusted a wider range of local legislative authority. The colonies of new England had, moreover, been founded under peculiar auspices. They were the refuge of the Puritan Parliamentarians, who emigrated from England in considerable numbers previous to what has been courteously called "the great rebellion," and during the period which elapsed from the restoration to the revolution. They were for a considerable time left to govern themselves, and they organized their simple society upon the footing of shire and town districts of England, and the representative system of England's parliament. They were verging upon republicanism when they laid the foundations of their colonies; and their experience of the royal governors sent out to them, and their disputes with the court respecting their charters, rather tended to confirm than to weaken such sentiments. The social relations of the other colonies, in which there was no idle class of society, were favourable to the growth of practical sentiments of the same kind, although devoid of the *prononce* theoretical republicanism of New England. The conquest of Canada by England, by removing a dangerous enemy from the American frontiers, removed the strong tie of fear which bound the mainland colonies to the native state. The growing population of the colonies made them feel more frequently the disadvantages of an absolute government; while, at the same time, their growing wealth and intellect conspired, with the removal of the French, to inspire them with a consciousness of being ripe for self-government. The colonists were in this perilous mood, chafed moreover by the proverbial insolence of official subordinates, when the oligarchical parliament of England adventured to infringe their prescriptive rights of taxing themselves. The consequence of the quarrel to which this ill-advised step gave birth is known to all: the establishment of a parliamentary power on the main-land of North America—such as was established in England upon the overthrow of Charles I, but whose founders, having more sagacity or more virtue than their English predecessors, drew closer, instead of cutting, the elective tie which bound them to the mass of the people, and thereby rendered the empire they had founded permanent.

This birth of a new state of European lineage in another hemisphere was an event calculated, under any circumstances, to attract the attention of Europe. But the piques and jealousies of European sovereigns rendered it influential upon the relations of the European system. There was an old and inveterate grudge between the governments of France and England, which had been considerably embittered on the part of France by the loss of Canada. France, therefore, marked with delight the growing ill-temper of the British provinces in America. It was not easy to foresee the consequences of the rupture at first, but it was enough for the French ministry that England might lose its colonies as France had done. At a very early period of the controversy, we find the French ambassador in London making friendly overtures to Franklin, the delegate for Pennsylvania and New England. When the American provinces declared themselves independent of England, France was the first to contribute aid in the shape of war-like stores, to promote a loan of money to the new government, and even to encourage French volunteers for the American armies. Several other European governments followed the example of France, impelled by similar motives.

All this was, on the part of the governments, mere spleen, and a base under-hand method of striking a blow at a feared and hated rival. On the part of the people, however, other motives were at work, and consequences ensued which their purblind rulers never dreamed of. At the time the American war of independence broke out, the fever that raged in the veins of European society was rapidly coming to a crisis. All were dissatisfied with existing social arrangements, and thirsting after a change. Even kings were aiming at the character of state-doctors, and cutting and carving away merrily at the old institutions of their realms. The simple healthy vigour of the Americans struck the enervated denizens of Europe with surprise. The Americans became the fashion, their institutions contrasted favourably with the effete institutions of the old world. The enthusiasm in favour of America was spread at Paris and throughout Europe, by the young and adventurous who found a campaign or two in America the surest means of acquiring notoriety. The spirit was diffused still more widely by the sordid spirits of some of the German potentates, who at that time sold their subjects to fight the battles of England in America. Frederick of Prussia, who, more than any man of his age, contributed to unsettle men's attachment to old institutions, and prepare them for innovation, lent double force to the indignation excited by such mercenary conduct by one of his practical jokes. By the laws of the empire he was entitled to uplift a certain toll upon all cattle driven through his dominions. He demanded this toll—so much per head—from the princes who marched the troops they had sold to England through his states. Germany in hatred, as France in friendship, felt the cause of America to be its own; and every taunt or invective uttered by the American republicans against kingly power was devoutly responded to in both of these states. In Holland, in the north of Italy, in Switzerland, the name at least of republics still survived. The prejudice in favour of representative institutions burned from one end of Europe to the other. England itself did not escape. The petty factious efforts of Wilkes and others had affected to speak in language similar to that which was subsequently uttered by the Americans. The phrase, "taxation without representation is tyranny," was responded to by many in Great Britain. The American delegates had formed several enduring friendships in England. The eloquence of Chatham and Burke had rendered their cause in a manner classical. The expenses incurred in the vain attempt to put down America, and the consequent increase of taxation, diffused a spirit of disaffection. From this time the cry for parliamentary reform became more deep-mouthed and incessant.

It was in France that events first called into activity this latent but all-pervading spirit of disaffection. But it could no more be confined to France than the Lutheran controversy could have been confined to Germany. The educated classes throughout Europe felt as one people. What paralyzed industry or shook credit in one country of Europe, was conveyed with the rapidity of the electric spark passing along the chain to all the others. The example of America was the lode-star of all eyes. These circumstances were enough to make the subjects of every government in Europe look with sympathy and emulation to the first outburst of the French Revolution: the rulers with aversion and apprehension. It was not possible that the French Revolution could go off peaceably. The institutions of the state were so thoroughly and essentially rotten, that to teach them the purposes of reform was to see them crumbling beneath the hand. There was not in the nation the power to replace them. There were none but the most incarnate diplomatists who had any practical knowledge of public business. There was not even the self-denying virtue and patience requisite in such an emergency. Under the old system men had been made virtuous in theory, but vicious in practice. The almost unendurable miseries, suffered under the *ancien regime*, seemed to gain in intensity through the attempt to cure them. Between the blundering impatience of reformers, and the dishonest counteraction of the court, the nation was goaded to madness. Blind partisan fury took the place of controversy. The neighbouring sovereigns assumed the attitude of arbiters, "and by decision more embroiled the fray." Europe flew to arms, and from the time of the invasion of Champagne by the united Austrians and Prussians down to the battle of Waterloo, may be regarded as one long war. As might have been expected all parties forgot at times, in their ardour and rancour, their ostensible principles. Men saw the French advocates of equality stoop to a more iron despotism than their country had ever known before. They saw in Spain and Germany the very men who had raised the war-cry of the unprescriptible rights of kings, catching in grovelling supplication the people's knees.

The present is but a breathing time, for the controversy is far from being settled. In England, France, Spain, Portugal, Belgium, Holland, Greece, Norway, and some of the German states,

representative institutions have been established. In Sweden, and in several German states, a substitute, more spurious than real, has been constituted. Russia, Prussia, and Austria, and their dependent allies in Italy and Germany, adhere to the monarchical principle. But even among the nominally constitutional, or representative governments, the basis of the constitution is still far from being satisfactorily adjusted. It is eagerly discussed whether the monarch gives the representative chambers to the people, or receives his sovereign authority from them. Here is a source of internal discord which must unavoidably spread beyond the boundaries of the first state in which it originates. The more readily that the despotic states only tolerate the existence of the representative states in their neighbourhood, because they cannot prevent it, fearing the influence of their example upon their own subjects, the slightest pretext for interference will be the more eagerly grasped at. While, on the other hand, the long wars in Europe, and the unsuccessful attempts at revolution in some of the despotic states, have nursed up bands of homeless resolutes, forced by circumstances, as much as by inclination, into a state of eternal war with the arbitrary powers. These men pass from land to land striving to stir up commotions, traders in the commodity of revolution, *voyageurs de la maison de Lafayette*, as they have been sportively called. To conclude, the altered relations of rulers and subjects in the constitutional states of Europe, have rendered important changes necessary in several of the old established regulations of international law; but this cannot be so easily effected while states endure in Europe, hostile to the constitutional doctrines regarding the rights of the people. The present European arrangement is interim and definitive. Canning's war of opinion, already postponed much longer than could have been expected, may be still longer delayed, but come it must.

IMPROVED SHOOTING AND MITRE SAW BLOCKS

BY MR. G. HOLDING, MANCHESTER.

THESE two simple implements have been found to effect a very considerable saving in the time ordinarily required for testing the accuracy of planed or sawn angles by the use of set squares or templates. When the workman has nothing more to guide him than his eye and hand, the former instruments are continually in request, and their constant use, even in the hands of the most skilful operator, does not always succeed in producing the best work.

Fig. 1 of our engravings, represents a longitudinal section of Mr. Holding's shooting block. Fig. 2 is a transverse section. A A, is the iron bed of the plane, grooved to receive the feather of the sole of the plane, B, which slides upon it and carries two cutting irons. C C, brass fences, adjustable to any angle by the set screws, E E. No further explanation will be required to see that the fences, C C, may be instantly set to any required angle, without risk of the slightest alteration. The necessity for turning the mould face side down, is obviated by the introduction of the two irons in the plane; and the difficulty which the operator generally feels in keeping the common plane close up against the mould, is done

Fig. 1.

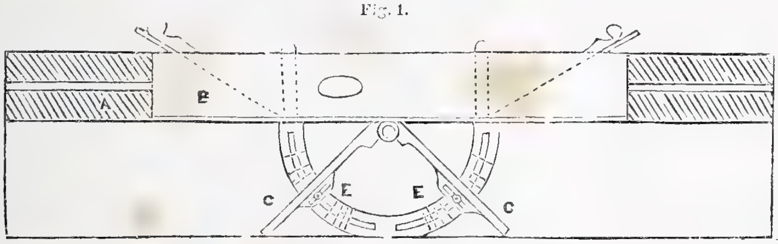


Fig. 2.

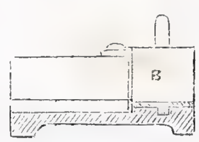


Fig. 3.

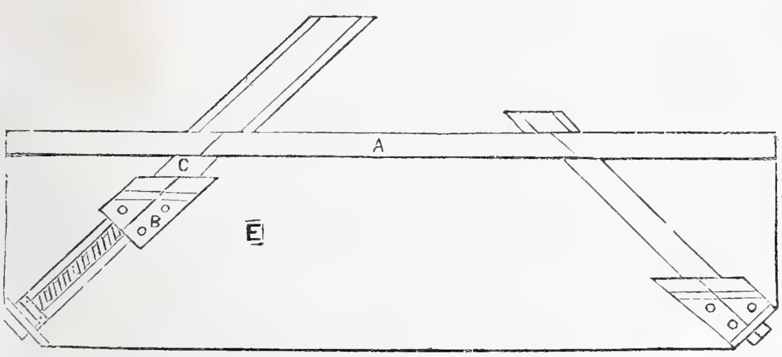
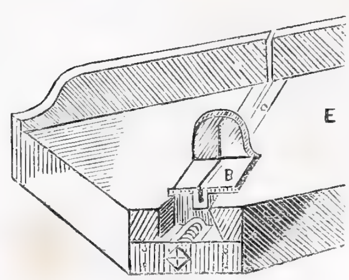


Fig. 4.

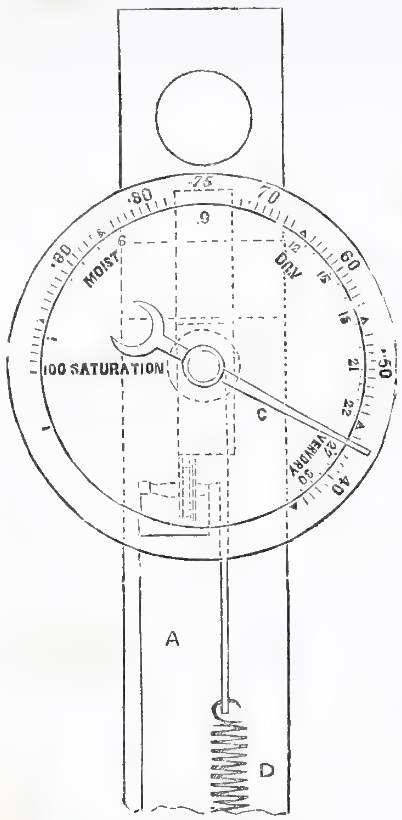


away with by the action of the tongued plate working in the bed, A. Fig. 3 represents the mitre saw block, with moveable front fences. A, is the back fence; B, front fence of brass, with boxwood faces; C, a dovetailed tongue, flush with the bottom, E, and passing under A; D, a fast screw, the nut being fastened to the under side of C. The perspective view, fig. 4, gives a clear idea of the construction of this instrument.

The objections to the blocks at present used are, that with one fence at the back they are not sufficient to steady the saw; or, when provided with two fast fences, a loss of time results in cutting small moulds, by reason of the handle coming in contact with them. Again, the size to be cut must be guessed at from the back of the mould. In Mr. Holding's block, the fences are the depth of the saw-blade, which prevents the bottom being cut. The fences may be opened to any width of mould, and perfect exactitude of cut is imperative, from the fact of the *sight* edge being always against the front fence.

PORTABLE HYGROMETER.

The improved hygrometer, registered by Mr. Simmons of London, is of very simple construction, and is so arranged as to show the exact humidity of the atmosphere in decimal parts of the saturation, as well as to afford a ready means of ascertaining the precise dew point. Our sketch represents a front elevation of Mr. Simmons' instrument, with the details dotted in. A, is the back or main supporting piece of metal or glass, to which is attached, at the lower extremity, a long thin strip of wood, the grain of



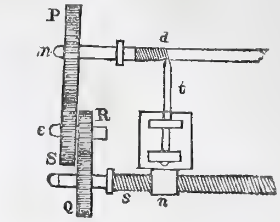
which runs in a direction transverse to the length of the strip. The upper end of this strip is attached to the axis of the index C, which points out the degrees of saturation of the atmosphere. A helical spring, D, is fastened at its lower end to a bracket projecting from the front of the back piece, A, its contrary extremity being fastened, by means of a connecting-cord to the index axis C. The action of the spring upon the index is such as to tend constantly to hold it at its original position, while the expansion and contraction of the wood slip, due to the greater or less amount of moisture in the atmosphere, moves the index round accordingly, and thus indicates upon the graduated dial the ratio of moisture existing at the time being.

The dew point is readily found by first ascertaining the exact temperature at the time of observation, and from this, subtracting the number indicated on the dial by the hand C, the remainder being the temperature corresponding to the amount of moisture in the atmosphere, or, as it is technically termed, the dew point.

ON THE CONSTRUCTION OF TABLES OF THE CHANGE-WHEELS EMPLOYED IN LATHES FOR CUTTING SCREWS.

As it is impossible to make a table so extensive as to embrace every possible case that may arise in this department of industry, it may be more generally useful to explain briefly the mode in which all such tables are constructed.

Let the diagram annexed represent the general arrangement of the mechanism employed in cutting screws. Here m is the mandrel or spindle of the lathe. Between this and the fast head of the lathe is fixed the cylindrical rod d, upon which the screw is to be cut, and which may be regarded as a continuation of the spindle; s is the main screw of the lathe; it is a long screw which revolves in bearings fixed to the lathe frame, and gives motion by means of the nut n, to a sliding table upon which is clamped the cutting tool t. The spindle carries a wheel P, and the main screw another wheel, Q,—these are connected either by a carrier-wheel upon the intermediate axis c, or by two change-wheels R and S.



In this arrangement, it is clear that every revolution of the screw s, will cause the tool to advance through a space equal to its own pitch; that is, if the main screw s have two threads in the inch, every revolution which it makes will advance the point of the tool half an inch endlong upon d; and if the spindle m revolve with the same velocity as the main screw, the tool will trace upon the surface of d, a screw exactly of the same pitch as s. But if m revolve with twice the velocity of s, then the screw cut upon d will have only half the pitch of the main screw s; that is, double the number of threads in the inch. To express this generally, let the main screw s have n threads in an inch; then every revolution which it makes advances the tool through the nth part of an inch, and will have cut as many threads, or parts of a thread, upon d, as the spindle has made revolutions, or parts of a revolution.

Now suppose, as is frequently the case, that the wheels P and Q are connected by a simple carrier-wheel upon the intermediate axis c, or what amounts to the same thing, suppose that the intermediate wheels, R and S, have each the same number of teeth, then it is clear that for every revolution which the spindle m makes, the main screw s makes $\frac{\text{No. of teeth in wheel P}}{\text{No. of teeth in wheel Q}}$ revolutions or parts of a revolution according as P or Q is the greater. For example, suppose the wheel P to have eighty teeth, and the wheel Q 120 teeth, then the velocity of s compared with that of m, is expressed by the fraction $\frac{80}{120}$, which reduced to its lowest terms is $\frac{2}{3}$. Now by a revolution of the main screw s, the tool is advanced through the nth part of an inch along d; but one turn of the spindle m corresponds to $\frac{\text{No. of teeth in P}}{\text{No. of teeth in Q}}$ turns of the main screw s, and therefore advances the cutting tool through the space $\frac{\text{No. of teeth in wheel P}}{\text{No. of teeth in wheel Q}} \times \frac{1}{n}$ inch;

that is, taking the numerical values of P and Q above, and taking $n = 2$, or to avoid confusion, suppose P and Q to have 80 and 120 teeth respectively, and the main screw to have two threads in the inch, then the expression above becomes $\frac{80}{120} \times \frac{1}{2}$ inch $= \frac{1}{3}$ inch, which is the pitch of the screw d cut by this arrangement.

If we wish to express this in the common way; that is, by stating the number of threads in the inch, we have only to find how often $\frac{1}{3}$ inch is contained in one inch; the quotient 3 is the number of threads in the inch of the screw d. But 3 is the reciprocal of the fraction $\frac{1}{3}$, and may be found by simply inverting its terms; in like manner the reciprocal of

$$\frac{\text{No. of teeth in wheel P}}{\text{No. of teeth in wheel Q}} \times \frac{1}{n} \text{ is } \frac{\text{No. of teeth in wheel Q}}{\text{No. of teeth in wheel P}} \times n$$

The first of these is the general expression for the pitch of the screw in parts of an inch, and the last for the number of threads in the inch, of the screw d. In calculating the change-wheels P and Q for a given pitch, we may use either of the expressions, but the last is commonly the most convenient.

Example.—Required the number of teeth of a pair of wheels P and Q, which shall give six threads in the inch of the screw d, the pitch of the main screw s being two threads in the inch. Our formula becomes for this question

$$\frac{\text{Teeth in wheel Q}}{\text{Teeth in wheel P}} \times 2 = 6;$$

That is, the wheels must be taken such that when the number of teeth in Q is divided by the number of teeth in P, double the quotient shall be 6. Now this condition is fulfilled by taking

$\frac{\text{Q} = 120,\ 90,\ 75,\ 150,\ \&c.,}{\text{P} = \ \ 40,\ 30,\ 25,\ \ 50,\ \&c.,}$ which are all equal fractions whose common value is 3; and as required, twice this is 6. Any of these pairs of wheels may therefore be employed, and it only remains to consider which pair can be employed most conveniently.

But suppose that the question had required us to find a pair of change-wheels to cut a screw of 17 threads in the inch, then the quotient arising from the division of the number of teeth in the wheel Q by the number in the wheel P ought to be $8\frac{1}{2}$, that is half of 17. Now, it is not desirable that P should have fewer than 14 teeth; therefore Q must have as many as $8\frac{1}{2}$ times 14, that is 119 teeth, and both may have any multiples of these numbers, as $\frac{119 \times 2}{14 \times 2} = \frac{238}{28} = 8\frac{1}{2}$. But these numbers are not such as would be adopted for wheels intended for purposes of this kind, and therefore it becomes necessary to introduce another pair of change-wheels R and S, instead of the simple carrier-wheel, by which we have hitherto supposed the wheels P and Q to be connected. But from the nature of the mechanism R, and S make each the same revolutions, being upon the same axis, and their effect upon the arrangement is therefore in the ratio of the number of teeth in S to the number of teeth in R; that is, $\frac{\text{No. of teeth in S}}{\text{No. of teeth in R}}$; and by compounding this expression with that already found for the two wheels P and Q, we get the general rule—

$$\left\{\frac{(\text{No. of teeth in Q}) \times (\text{No. of teeth in S})}{(\text{No. of teeth in P}) \times (\text{No. of teeth in R})}\right\} \times n = \text{No. of}$$

threads in the inch of screw d. Let us apply this rule in finding a set of four change-wheels to cut a screw of 17 threads in the inch as above proposed; the condition is that the numerator divided by the denominator of the above expression shall be $8\frac{1}{2}$. Now, suppose we fix upon 45 and 90 as very convenient values of P and Q; that is, take P and Q such that

$$\frac{\text{No. of teeth in Q}}{\text{No. of teeth in P}} = \frac{90}{45} = 2$$

then it only remains to find values of R and S, such that

$$\frac{\text{No. of teeth in S}}{\text{No. of teeth in R}} = 8\tfrac{1}{2} \div 2 \ (\text{that is } \tfrac{90}{45}) = 4\tfrac{1}{4},$$

which shows that S must contain $4\frac{1}{4}$ times as many teeth as R. Now, a pinion of 20 teeth may be reckoned very convenient for R, and this being decided upon, S must have $4\frac{1}{4}$ times 20, that is 85 teeth. The whole set of wheels is thus found to be

$$\text{P} = 45,\ \text{Q} = 90,\ \text{R} = 20,\ \text{S} = 85,$$

and the proof is, putting for n its numerical value 2, that

$$\frac{90 \times 85}{45 \times 20} \times 2 = 2 \times 4\tfrac{1}{4} \times 2 = 17$$

the number of threads in the inch of the screw d to be cut.

It may happen, however, that this particular arrangement is not desirable, and if so, a new calculation must be made. Thus, suppose it desirable that P and Q have 60 and 85 teeth respectively, then R will be a pinion of 15 teeth, and S a wheel of 90 teeth.

$$\text{For } \frac{85 \times 90}{60 \times 15} \times 2 = 17 \text{ as before.}$$

This is found by the same process of reasoning as before, and several other arrangements may be determined in the same way.

In these calculations we have assumed $n = 2$, that is, that the main screw of the lathe has two threads in the inch. This is the most common pitch, but the form of calculation is the same whatever be the value of n. To express this generally our rule becomes

$$\frac{(\text{No. of teeth in Q}) \times (\text{No. of teeth in S})}{(\text{No. of teeth in P}) \times (\text{No. of teeth in R})} = \frac{\text{No. of threads in inch of screw } d}{n}$$

that is, the quotient arising from the division of the numerator by the denominator of the first fraction, must always be equal to the quotient arising from the division of the number of threads in the inch of the screw to be cut by the number of threads in the inch of the main screw of the lathe. Thus suppose the main screw to have a pitch of 3 threads in the inch, and that we require to cut a screw of 23 threads in the inch, our arrangement may be

$$\frac{(\text{Q} = 120) \times (\text{S} = 115)}{(\text{P} = 90) \times (\text{R} = 20)} = \frac{d = 23}{n = 3} = 7\tfrac{2}{3}$$

What has been said above, taken in connexion with the table at p. 494, from which examples for trial may be selected, will, it is believed, remove all difficulty in understanding the nature of calculations of this sort, and render any additional table of change-wheels unnecessary.

The arrangement for barrel-turning by the self-acting lathe, does not differ essentially from that employed in screw-cutting; the motion by which the tool traces the cylinder, is precisely the same as when it cuts a screw, only the spiral thread is much closer. In screw cutting, the tool makes usually from 4 to 50 cuts in the inch, but in turning cylinders, the cuts extend from 50 to 1000 in the inch. The particular contrivances by which this slow motion of the tool is produced, will afford us matter for some future remarks.

PORTABLE AIR-PUMPS.

THE following are two designs for single-acting double-barrelled air-pumps, each possessing peculiar claims for simplicity and compactness.

Fig. 1.

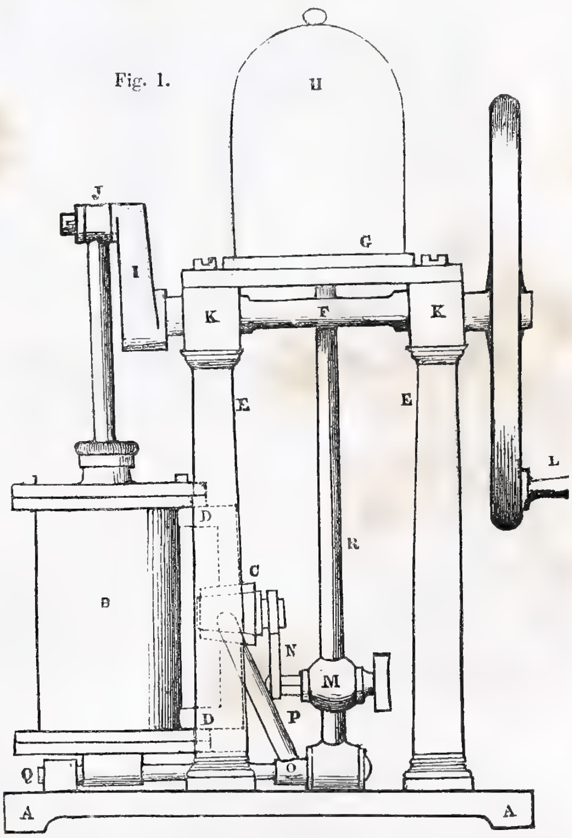


Fig. 1, with the following description, will make the first sufficiently plain. A A is the stand; B, an oscillating cylinder (or barrel); C, a four-way cock (instead of the clack valves), communicating with the top and bottom of the cylinder by

the pipes, D D; E E, are two (of four) pillars for supporting the crank-shaft, F, the pump-plate, G, and the receiver, H; I, the crank connected to the top of the piston-rod by the boss, J; K K are two steps for the crank-shaft to turn in; L, the handle for working the pump; M, a stop-cock for shutting off the communication between the pump and receiver; N, the lever to work the four-way cock, the end of which is held stationary by a slot in the plug of the stop-cock, M; O, a common swivel joint, to support the cylinder, and allow the air to pass from the receiver up the pipe, P, to the pump; Q, is the other step for supporting the cylinder.

It will be seen, by attention to the drawing, that, by turning the handle, L, the piston of the pump will be moved up and down, and by the vibration of the cylinder the four-way cock will be moved backwards and forwards, whilst the lever fixed to its plug will be kept from moving (as before) by the hole in the plug of the stop-cock, M; therefore, the four-way cock will be opened and shut at the proper times. It will be observed that, by reversing the motion of the handle, L, its action will be changed into a forcing pump.

Fig. 2 represents another form of air-pump. A is the stand; B, a pillar, which carries the crank-shaft; C, passage to receiver; D, cylinder; E, countersunk face, between which and the steel centre, F, the cylinder vibrates. The conical face, E, which is firmly fastened to the cylinder, has two passages, as shown in fig. 3—the face in which it works has four, as shown in fig. 4;

Fig. 2

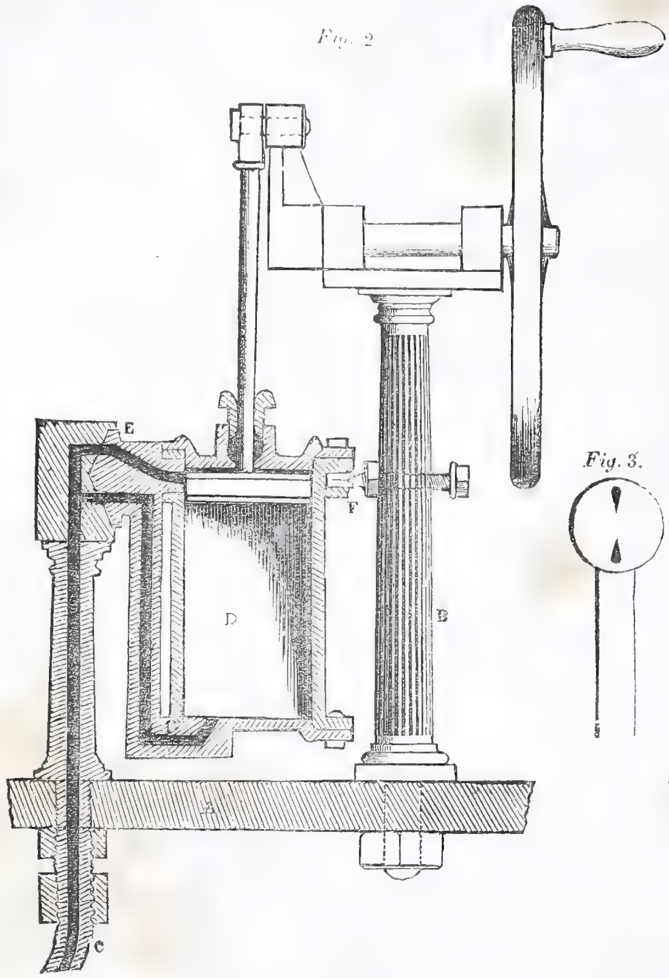
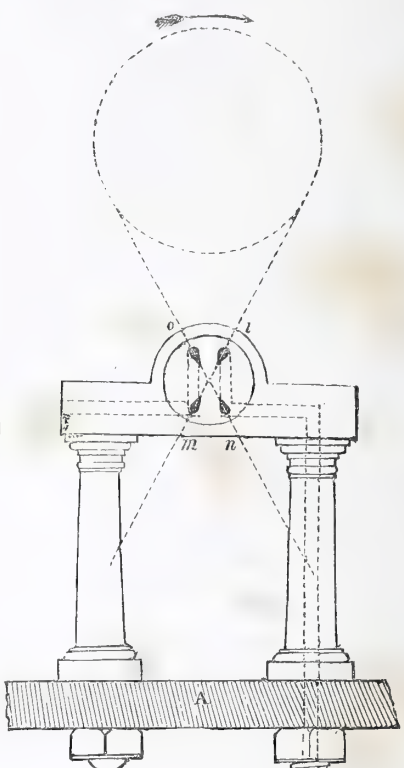


Fig. 3.

Fig. 4.



two of which communicate with the receiver, and the other two with the atmosphere. It is obvious that, by turning the handle in the direction indicated by the arrow, a communication is open with the receiver during the down-stroke of the piston through the passage, *l*, at the same time the air of the cylinder is expelled through *m;* during the up-stroke it is exhausted through *n*, and expelled through *o*. It is converted into a force-pump by reversing the motion; and by admitting steam through the pipe, C, it works very tolerably as a high-pressure engine. A small one, about the size of the drawing, will make 200 strokes, that is, 100 revolutions of the crank in a minute.

IMPROVEMENTS IN MACHINES FOR CLEANING AND SIFTING CORN AND SEEDS.

BY MM. JEROME, BROTHERS, ENGINEERS, AMIENS.

The improvements introduced by MM. Jerome, Brothers, into the machines in use in certain districts of France, for cleaning corn and seeds, embrace several points of importance, namely:—

1. A new and peculiar arrangement of the organ, which they call the *winnowing-pipe*; an arrangement which has for its object to facilitate the passing out of the corn, and at the same time to increase the action of the air driven by the fanner, properly so called, which serves at the same time for cleaning and winnowing the grain.

2. The arrangement of the sieve, or riddle, placed over the

drum, and which admits of being made exactly the same length as the latter.

3. A simplification of the mechanism for moving the riddle, by connecting it directly with the axis of the fanner itself.

4. The peculiar construction of the whole apparatus, with frame of cast-iron, for driving it either by a constant mover, or simply by turning a handle.

5. The new make of the gearing teeth applied to these machines, especially when worked by the hand.

We shall endeavour to explain these improvements by means of the detailed description which follows, with the aid of the annexed figures.

Fig. 1 represents a front exterior view of an improved machine, such as we have described, constructed with its frame of cast-iron.

Fig. 2 is a vertical section made through the axis of the drum and fanners.

These machines serve at once to winnow, riddle, and clean the grain, and are suitable for all kinds of corn. The different working parts are arranged so as to occupy little space, and to effect the various operations in a steady and uniform manner, requiring but little motive power. Moreover, they have not only the recommendation of being in large demand in certain districts of France, by the proprietors of mills—especially wind mills—but still more by the agricultural interest, and in particular by all farmers who fully comprehend the fact, that their grain brings them a higher price when it has been previously well cleaned.

The machine contrived by the Brothers Jerome accomplishes this object, inasmuch as it is both simple in construction, and thoroughly cleans the grain, performing the work in little time, and with little aid from manual labour.

The frame in which the whole machine is enclosed, consists simply of two cast-iron cases, A, which form an advantageous substitute for the wooden frame, and are indeed greatly preferable to the latter, inasmuch as they are more solid and less liable to alter with changes of temperature.

As in other machines of the kind, the corn to be cleaned is first thrown into a hopper, B, from whence it falls into the riddle, C, by which the straws and all other foreign bodies larger than the grain are removed. This riddling-box receives a jerking motion directly from the cam, fixed at the extremity of the horizontal iron shaft, E, which carries the vanes of the *thrasher*, properly so called.

Fig. 1.

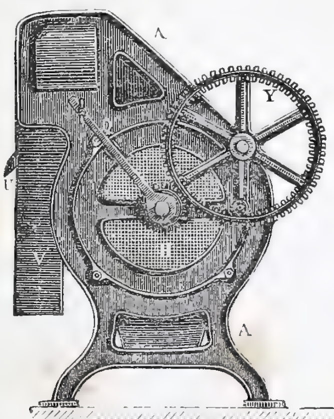
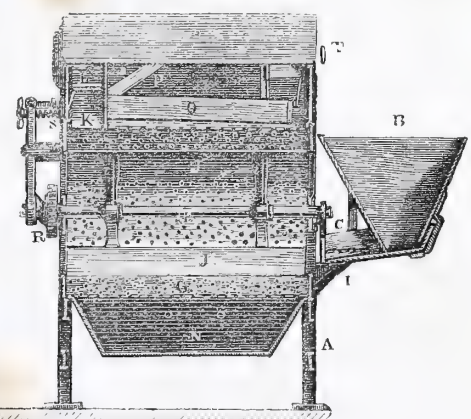


Fig. 2.



The riddled corn falls by the inclined sluice, I, towards the lower part of the fixed drum, G, formed of rasped sheet-iron, having its rough side inwards, and which, at its opposite ends, is closed with a metal grating, H.

The horizontal shaft, E, carries two series of arms, *i*, to which are attached the wooden paddles, J, and these are in like manner furnished with sheet-iron rasped on the surface, so that, by the rapid rotation communicated to the axis, they beat the corn against the interior of the drum, and raise it, while being subjected to this process of thrashing, to the upper part, whence it proceeds by the channel, K, towards the end of the machine into the box, L, closed in front by a cover of wire gauze, through which passes the air that is driven at the same time by the vanes and paddles of the thrashing machine.

All the dust which is thus disengaged from the corn passes from the drum through its various little openings into an exterior case, and is then delivered into a kind of trough, N, which constitutes the lower part of this exterior case. The dust is removed, when desired, by a small door of sheet-iron.

The cleaned corn falls from the box, L, into the riddle, O, in proportion as it is winnowed by the air from the paddles, J, which air escapes by the passage, P.

This riddle or sifter, which has for its object to separate all the small seeds and dwarf grains from the good corn, receives also, like the first riddle, an oscillating movement, more or less energetic, by means of the lever, Q, which, at its lower extremity, carries a knob that is acted on by the cam, R, fixed near the end of the horizontal shaft, E. A spiral spring, S, the tension of which may be regulated at pleasure, permits, with the aid of an abutting screw, to limit to any required extent the oscillatory movements of the riddle.

All the good corn which passes out at the lower end of the riddle is delivered into the inclined sluice, U, from which it may be received into a sack; and all the refuse which has passed through the holes of the sieve descends into the hopper, or receptacle, V, at the bottom of which is a door for the purpose of removing it when necessary.

When the machine is intended to be fitted to a mill where it may be driven by a constant force, a fixed cast-iron pulley, connected with the main shaft of the machinery, is mounted at the end of the horizontal shaft, E; and a loose pulley is also provided, to allow of interrupting the movement at pleasure.

When, on the contrary, the apparatus is intended for a farm, where it is generally driven by the hand, a toothed pinion is applied to the shaft, E, and this gears with a large wheel, Y, to which a handle is fitted. The teeth of this wheel are made of wood, but of a particular construction. They are dovetailed into the iron circumference of the wheel, so as that the wood is surrounded with the metal on three sides. In this way, each of the teeth is much more solidly fixed than by the usual method; and still the important point is attained of having wood in contact with metal, since it is only the projecting part of the teeth of the wheel that is brought into contact with those of the pinion.

Messrs. Jerome have thought of adding to their apparatus a very simple arrangement, which permits of collecting separately grains of different kinds and sizes that have been mixed together—in a word, which performs the part of a *sorter*, while at the same time the work of cleaning is accomplished.

Their process consists in placing within the riddle several pieces of wire gauze of different degrees of fineness, the one over the other; and making these correspond to the different

sizes of the several kinds of grain to be collected. Their new riddle consists of two pieces of wire gauze placed in this manner, and separated only by a small interval; the first corresponds to a space in the receptacle for the siftings, V; the second is connected with the outside of the machine by a sluice, U; this second form is exactly the same as that already described.

The effect produced by this arrangement is as follows:—The mixed grains of rape and poppy-seed, for example, fall on the upper wire sieve, the poppy-seed passes through and falls on the second, while the rape-seed, being larger than the poppy-seed, travels over the upper sieve, and falls out at the end of the riddle into a separate receptacle. The poppy-seed is separated from the refuse siftings by the lower sieve of wire gauze, through which the latter pass and fall into the reservoir, V, while the good grain arrives at the sluice, U, from which it is received into a sack.

CAOUTCHOUC THREAD MANUFACTORY.

Messrs. Aubert and Gerard have established at Grenelle, near Paris, a caoutchouc thread manufactory, the flourishing condition of which, and the quality of its products, induce us to reproduce the following report, which we extract from the *Bulletin de la Société d'encouragement*:—

The manufacture of which we are about to speak is thoroughly French; on this point there can be no doubt. The factory is at Paris, close to the bridge of Grenelle, and is the only one of the kind in existence. The business consists in the manufacture of round caoutchouc thread, of indefinite length, by means of pressure. Up till the time when the process of Gerard and Aubert appeared, for preparing the caoutchouc thread required for the manufacture of elastic fabrics, no other method was known than that of cutting mechanically, or with scissors, either the caoutchouc in bottles (*poires*), or natural caoutchouc (as the ball-makers of our colleges do), or *regenerated* caoutchouc, that is to say, caoutchouc kneaded with essential oil, and made into sheets. This method, still employed in the large manufactories, of which the small factory at Grenelle has become the rival, gives, as may be conceived, flat threads, which are limited both in length and thickness; whilst the process of Gerard and Aubert produces threads perfectly cylindrical, quite unlimited in length, and the size or thickness of which may be varied to any extent.

The small factory of Grenelle is constructed in all respects on J. B. Say's principles—without pillars, without mouldings, formed of simple sheds, merely sheltered from the wind and rain; but one finds in it an excellent stock of machinery commodiously fitted up, and supplied with an ample moving power—the whole performing with ease and producing regularly, in the midst of a truly remarkable assemblage of ingenious and scientific arrangements, all stamped with the seal of excessive simplicity. The caoutchouc arrives there in any state—in bottles (*poires*), in sheets, in waste-cuttings; it is immediately reduced, that is to say, divided in such a manner as to clean it as completely as possible. To effect this division, this *déchiquetage*, the stuff is thrown between two cylinders placed horizontally, and having their surfaces furrowed. These two cylinders are both put in motion, but the one goes quicker than the other; and during this operation the substance is subjected to the action of a current of water constantly renewed, which removes all the foreign bodies. The caoutchouc, thus teased and drawn out, forms a kind of cloth, or rather a skin-like shred, shagreened and punctured.

After the reduction (*déchiquetage*), comes the conversion into paste—the chemical operation, so to speak. The caoutchouc sheet is divided into small strips, which are introduced by hand into zinc boxes with wide openings; over the caoutchouc is poured, in the box, sulphuret of carbon, not pure, but containing about 5 per cent. of alcohol. The proper quantity to use is double the weight of the caoutchouc—a little more or a little less, according to the quality of the gum. This being done, the lid of the box is adjusted, fitting into a very deep groove, packed with tow, impregnated with a mixture of glue and treacle, or some other soft and humid substance, forming a kind of cement impermeable to the sulphuret of carbon. After macerating in the liquid twelve or fifteen hours, the caoutchouc is ready to use; it is not dissolved, as might be expected; it is only, if we may say so, *killed* (*éteint*); it is softened to the resemblance of flour paste, and may be kneaded in the same manner as it.

The sulphuret of carbon, employed alone, dissolves caoutchouc; alcohol, added to this solution, would precipitate it completely. The mixture seems to realize simultaneously these successive operations; it appears to dissolve and precipitate at the same time—in a word, to divide the caoutchouc.

This action cannot be better compared than to that of carbonate of soda on oils or fats, which are not dissolved by it, but rendered emulsive.

The caoutchouc paste is introduced into vertical cylinders, the lower ends of which are fitted with wire gauze, and in these, by means of a piston and pressure, it is sifted or strained repeatedly, to clean it and knead it thoroughly; it is then put into another vertical cylinder, somewhat similar to those which are used by the vermicelli-makers. The elastic matter, forced through by the piston, comes out in threads by small holes placed in a single row, in order that the threads may not lie over each other—a precaution that is not required in the making of vermicelli. The threads are received on an endless web of velvet in motion, and traverse in this way a course of 4 metres; they are then taken up by a web of common cloth, which passes over a space of 150 to 200 metres in about ten minutes. At the end of this journey they are sufficiently dried; the solvent is in great measure separated; the threads then quit the web, and are received into channels or grooves which conduct them into small cups disposed in seven rows, in such manner that each thread has its own particular cup. When the cups are full the thread is taken out, and is left for some days exposed to the action of the air.

The threads produced by pressure have any required thickness, and this may be made to vary at pleasure. Experience has shown that a thickness of 1 millimètre is preferable for regular work, but such threads do not suffice for all kinds of fabrics; in a great number of cases they must be used finer. Fortunately, Messrs. Gerard and Aubert are never at a loss for resources. By the latest and most ingenious process they can convert this too thick thread into thread of any required tenuity. Every one knows that caoutchouc thread may be drawn out with the least effort, and that, when this effort ceases, the thread returns to its former length; but what is not so well known, is the marvellous property discovered and so ingeniously applied by Messrs. Gerard and Aubert, we mean the annealing of caoutchouc. The caoutchouc being drawn out, and exposed to a temperature of 115° Cent., no longer shrinks, but retains the length it has acquired, and moreover may even be drawn out anew. By thus stretching and annealing it successively, a thread of caoutchouc may be brought to a degree of fineness limited only by the dexterity of the workman, and may, for example, be represented by a length of 50,000 metres to the kilogramme.

The thread thus obtained is of common caoutchouc, but nothing is simpler than to make, in the same manner, thread of vulcanized caoutchouc; for this purpose, it is only necessary to incorporate the caoutchouc into a paste with flowers of sulphur, and to heat to the temperature of 130 or 140 degrees Cent. Let us note, in passing, that at the temperature of 115 degrees, necessary for the annealing of the stretched thread, no vulcanization takes place.

Messrs. Gerard and Aubert can vulcanize by another process of their own, namely, by exposing the caoutchouc to the action of a temperature of 150 degrees (C.) in an alkaline polysulphuret. This process gives excellent results; there is, nevertheless, a difference, which permits the products of the one system to be distinguished from those of the other. The thread vulcanized with sulphur is grey, that vulcanized with the sulphuret remains black, as in a state of nature.

The two kinds of threads, the natural or the vulcanized, are employed in weaving, according to the special object in view: the natural thread is wound on bobbins, retaining its maximum extension; deprived of elasticity, it may be worked like any

other textile material; its elasticity is restored by passing a hot iron over the fabric. The vulcanized caoutchouc can be employed in weaving only by the aid of a peculiar artifice—it must be kept extended by weights.

Such is the ingenious process with which Messrs. Aubert and Gerard have enriched France; the products of their manufacture have passed through the ordeal of everything new and ingenious; they have had to struggle against the inexperience or the routine practice of the workmen, the bad will of rival interests, and the commercial monopolies. At this day they have taken their place, not only in France but in England, or rather, to speak more correctly, not only in England but even in France. The good work of the inventors has found its reward. Their efforts have been crowned with a well-merited success.

Messrs. Gerard and Aubert have combined, with their caoutchouc business, a sulphuret of carbon work; they at present deliver this product to the market at the price of 1 fr. 50 the kilogramme.

AGRICULTURE.

CHAPTER XIV.

ON RECLAIMING WASTE LAND.

The first thing to be done with waste land that it is intended to reclaim, is to drain it, then to prepare a working soil and flat surface, by means of ploughing, trenching, and subsoiling, and then it is usual to apply lime. In the few remarks that will constitute this chapter, we propose to consider, of course briefly, all these operations, except that of draining, which has already received our attention.

If, when the waste land has been drained, it will plough, the plough is always preferred. But very often this implement cannot be employed upon waste land. Where there have been trees, for example, their roots form a perfect bar to its progress. Again, deep moss that has lately been reclaimed will not sustain the weight of the plough and horses. Also upon very wet ground, ploughing will often be impracticable. In all these cases the land must be trenched.

This process of trenching should extend to a depth of sixteen inches. Its cost will, of course, vary with the rate of labour and the kind of land. Perhaps £6 per acre is about the average.

After the ground has been thus reclaimed, the surface is made level; it is ploughed in ridges, and becomes ready for a crop. The crop, perhaps, the most commonly fixed upon for the first, is oats; why, it is difficult to say, as it seldom succeeds. It is far better to manure it well, and take a root crop, either potatoes or turnips. The latter are the preferable crop, as they may be consumed on the spot by sheep, a process that will put the land at once into heart, and, moreover, give it that consolidation that it, in nine cases out of ten, stands in need of.

Very frequently, however, newly-reclaimed land receives a liming, and all land, or nearly all land, occasionally undergoes this process. A few observations upon this application of lime to the land, will, therefore, not be here out of place.

Lime has been for long applied to the soil, but it is only of late years that its action has been intelligible. We should say, its actions, for it has several. All plants contain a little lime, and, therefore, all fertile soil must contain it. If a soil be deficient in it, lime applied in any form supplies the deficiency. Then caustic lime promotes the decomposition of organic matters, and their conversion into humus. Farther, lime combines with acids, which acids would sometimes seem to be injurious to vegetation. Lastly, lime has a mechanical action, reducing the stiffness of heavy clay lands.

The usual mode of putting the lime upon the land is as follows:—When obtained from the kilns where the chalk (carbonate of lime) has had its carbonic acid expelled by heat, it is in lumps. Upon these water is poured, and a hydrate of lime is found, which is in the state of a crumbling powder. It is then carted away in old carts, and spread upon the land by means of a rather peculiar-shaped shovel, called the frying pan, or lime shovel. The horses and the harness are covered with a cloth, and the men should have their faces protected by pieces of crape. The horses, when the operation is over, should be very carefully groomed.

After the lime has been spread, it is covered in by harrows. The quantity employed varies from seventy to two hundred, and sometimes more bushels per acre.

In the neighbourhood of Edinburgh, and probably other large towns, the land does not require liming; the reason being that the police manures contain so much lime in the form of oyster shells.

In many parts of England, instead of caustic lime, chalk is used, and with advantage. The action of chalk is the same as that of lime, save that it does not promote decomposition of organic matter.

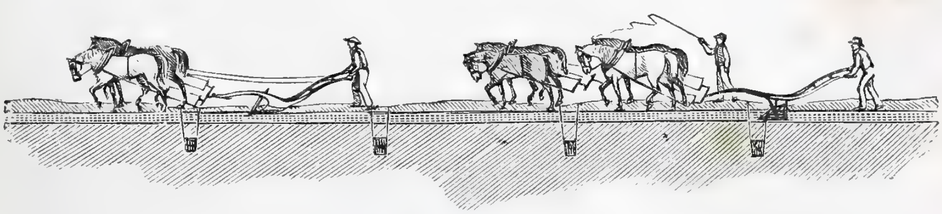
Theory would indicate that the best time to apply lime is to lea land just ploughed.

Trench and subsoil ploughing are usually practised upon land that has been long in cultivation, but belong to this section of our subject, as, in point of fact, they are means of reclaiming and putting to use portions of the subsoil previously of no use.

The difference between trenching by the spade and these operations, consists in the fact, that on them the subsoil is not brought to the surfaces, but merely loosened. This is often a great advantage, as the elements that compose the subsoil are often combined together in states that are poisonous to plants, and require a little time to enter into fresh and innocent union with one another.

It is of importance in subsoiling, to be sure that the subsoil about to be stirred is in a dry, friable state. If it be not, more harm than good follows the process. This is the reason that subsoiling is often noticed to be more beneficial when it follows after a crop or two thorough deep draining.

It is best done across the ridges, and the way it is managed is this. A common plough, drawn by two horses, goes first, and turns up a furrow of about eight inches. This is followed by the great subsoil plough drawn by four horses, which goes



in the furrow just made, and penetrates eight inches deeper. In this way, a depth of sixteen inches altogether is attained.

Several kinds of subsoil ploughs have been contrived. Perhaps the best is the Marquis of Tweedale's, but it requires a special plough to go before it.

As a proof of the good effected by subsoiling, we may state that a farm belonging to the Marquis of Tweedale was not, some little time ago, worth more than eight shillings a year an acre. It was drained, and after a time subsoiled, and its value went up to two pounds per acre of yearly value.

CHAPTER XV.

ON WATER MEADOWS.

Properly constructed water meadows, *i. e.* meadows that can be flooded, are, if rightly managed, very profitable. Almost all

water contains in solution some or all of the chemical elements that compose the food of plants, and when so, they are applied so intimately, and in such a proper state of solution, that the grass plants take them up with incredible rapidity. Aberdeenshire is not a very favourable locality for making water meadows, because the water of it, as of all granite countries, is very pure; but the proceedings of Mr. Simpson have there proved eminently successful. This gentleman states, that "previous to the ground being operated upon for the purposes of irrigation, the burn ran through the den in a winding course. The ground at the top of the den consisted of a few mossy hillocks, and the other part of the ground was pretty level, of a dry nature, and covered with a short grass. The ground was never cropped with grass, and the grass was not in use to be cut. The cattle were occasionally turned out upon it when pasture was scarce in the other parts of the farm. The soil generally, except the mossy parts, is alluvial in some places, and at others gravelly." In November, 1843, this piece of ground was irrigated, and the process repeated at intervals until May. It was cut first in June, and continued to be cut until October. It was treated much in the same manner the following years, and the crops obtained were:—

	1844.	1845.
Cut in June,	12 cartloads,	13 cartloads.
" July,	32 "	36 "
" August,	34 "	43 "
" September,	30 "	42 "
" October,	11 "	8 "
	119	142

The weight of each of these cartloads was 6 cwt. To ascertain how much hay could have been procured, one load was made into hay, and the yield was nearly 3 cwt.; to be exact, 2 cwt. 104 lbs. The field was 4 acres, 1 rood, and 38 poles. The hay then that might have been afforded by this field in 1845, would have been 495 stones, of 22 lbs. to the stone. This, at 6d. a stone, would have sold for £52. 17s. 6d., or £12. 7s. 6d. an acre.

In order, however, to obtain similar results, water meadows must be correctly constructed and carefully managed. A slow sluggish stream, deeply clogged with earthy impurities, is, if possible, to be selected as the source of the water. It is useless to construct a water meadow, unless an abundant supply of water can be depended upon, or unless the meadow be thoroughly drained. In fact, the art of irrigation consists in having plenty of muddy water, and in never allowing it to stagnate about the plants.

A water meadow must, of course, have a slope, and the most convenient form is when it has a very gentle one, from one side of the field to the other. A ditch is made from the brook, or other course of supply of the water, to the highest corner of the field. At the point where it enters the field, a sluice should be erected. In making this, it is necessary that the foundation go a good way down, so as to prevent any water passing when the sluice is put down.

A deep ditch, called a main conductor, is then made with a gentle slope the length of the field leading from the sluice. It must be of sufficient capacity to contain enough of water to flood the whole field. On the opposite and lowest side of the field is a similar ditch, called the main drain; the office of which is to convey away the water from the field, when the purposes of irrigation have been served. From the conductor proceed small channels, which terminate a little distance from the drain; these are called feeders, and run along the crown of the ridges; then as many smaller drains, deeper than the feeders, arise in the furrows, nearly at the conductors, and end in the main drain.

If, as will often be the case, the meadow has not one uniform slope, of course various modifications of the above plan will be necessary; but as these will differ in every particular instance, it is impossible to describe them. He who understands the principles, can have no difficulty in applying them as circumstances may arise. In like manner, the cost varies from £2 to £4 per acre.

The following is Mr. Lawson's mixture of grass seeds for water meadows for an acre:—

	Light Soils.	Medium Soils.	Heavy Soils.
Agrastis tolonifera (marsh bent grass),	3	3	3
Alopecaunus pratensis (meadow foxtail),	2	3	3
Festuca loliacea (spiked fisure),	4	5	5
" pratensis (meadow fissure),	2	2	2
Glyceria fluctans (floating sweet grass),	1½	3	3
Lolium perennus (ryegrass),	10	10	10
or	5	5	5
Lolium Italicum (Italian ryegrass),	3	3	3
Poa trivialis (meadow grass),	3	3	4
Phleum pratense (Timothy grass),	1	2	3

Along with these seeds, a bushel of barley or rye is sown to protect the young grasses. If the sowing is made in autumn, then rye is taken; if in spring, barley. It is also recommended to use, in addition to these, two pounds of the Solus major, or the greater bird's-foot trefoil.

The great authority upon the management of a water meadow is George Stephens, the author of the "Practical Irrigator." From that work we extract the following directions:—"At the beginning of the month of October, each feeder and drain should be cleansed, and the banks of the feeders repaired where they have received damage by the treading of the cattle. The whole works being repaired, and there being generally water enough at this season, either for the whole or part, the sluice should be drawn, when, in the course of half an hour, the conductor and the upper part of the feeders will be nearly filled. The first operation of the irrigator is to adjust the water in the conductor, or, if the meadow is in more parts than one, the water in each conductor must first be regulated. Then he commences anew by regulating the stops* in the first feeder; but should there not be sufficient water in the feeder, a little more must be let in by making the aperture wider or deeper, till the water flows regularly over the sides from one end to the other. From the first he proceeds to the second feeder, and so on, until the water in all the feeders is adjusted. Let the beds of a water meadow be ever so well formed, yet, by some places sinking more than others, or by the ice raising the surface of the ground, although the water along the banks of the feeders has been ever so nicely adjusted, it often happens that there may be some places between the feeders and drains with too little water, when it will be advisable for the manager to make a third feeder, redressing inequalities of the surface, so as to give every spot one inch deep of water. Every part of the works being regulated, the water should be allowed to run through the whole of October, November, December, and January, from fifteen to twenty days at a time without intermission. At the expiration of each of these periods, the ground should be made completely dry for five or six days to give it air, for there are few species of the grasses which form the most nutritive part of the herbage of water meadows that will long exist under an entire immersion under water. Moreover, if the frost should be severe, and the water begin to freeze, the watering must be discontinued, otherwise the whole surface will become one sheet of ice; and whenever the ice takes hold of the grass, it will undoubtedly draw it into heaps, which is very injurious to meadows. The object of this early watering of the meadows is to take advantage of the autumnal floods, which bring with them a variety of putrescent matter, which is found very enriching to land. It is the chief object of the irrigator in those months, to collect as much of this manure as possible, and at the same time to shelter the land from the severity of frosty nights. It is, therefore, requisite to use as much water as the land will carry without guttering. I believe that it would be difficult to give land, with a dry subsoil and considerable descent, too much water before the weather begins to get warm."

There can be no doubt that water meadows might be very advantageously multiplied. Near towns, irrigation with sewer water produces most astonishing returns. Of late there has been a growing opinion that, of all grasses, Italian ryegrass is best suited for this. It is very probable, that were an ordinary

* Stops, we should observe, are pieces of wood, &c., placed across the conductors or feeders, if the water tends to flow too fast.

water meadow sown with this grass, and top-dressed from time to time with portable manure, a very great improvement would be introduced into farming.

THE SCIENCE OF PHRENOLOGY.

ORDER I.—FEELINGS.

GENUS II.—SENTIMENTS.—*(Continued.)*

14. VENERATION.—This sentiment produces respectfulness and reverence in general. In its supreme functions, it induces worship and adoration. It is situated at the middle of the coronal aspect of the brain. Dr. Gall thus relates its discovery (Works, Vol. V., p. 216) :—"There were ten of us in the house of my father—my brothers and sisters and myself. All received the same education, but our faculties and tendencies were very different. One of my brothers, from his infancy, had a strong tendency to devotion. His playthings were church vases, which he sculptured himself, copes and surplices, which he made with paper. He prayed to God and said Mass all day,

and when he was obliged to miss service at church, he passed his time at the house in ornamenting and gilding a crucifix of wood. My father had destined him to commerce, but he had an invincible aversion to the business of a merchant, because, he said, it forced one to lie. At the age of twenty-three years, having lost all hope of pursuing his studies, he fled from the house and turned hermit; five years after he took orders, and till his death lived in the exercise of piety and devotion."

The head of his brother, Dr. Gall declares, was very elevated at the part we are now reviewing. After numerous observations, the organ has been fully established.

Among the numerous exemplifications of this organ, never, perhaps, was there a finer instance than in the justly celebrated John Frederick Oberlin. (See his portrait, p. 474, Vol. I., col. 2.)

This model of the Christian religion—whose piety was cheerful, rational, and temperate—found the inhabitants of his parish, isolated in five different villages, poor, ignorant, agitated by heinous passions, and without the most necessary means of comfortable existence, but, by labouring unremittingly, he by degrees succeeded in changing their wretched condition. He taught them to cultivate potatoes, flax, and such vegetables as succeeded best in light and sandy soils. He laid out a nursery, in order to supply the peasants with trees of various kinds, and showed them the advantage they would reap by attending to their cultivation. He gave instruction to the children himself, teaching the younger to read, write, and calculate, while he lectured to the more advanced in age upon the cultivation of fruit trees, the principles of agriculture, and the useful and noxious qualities of the various plants which the country produced. He particularly accustomed them to cleanliness. The good pastor, with his parishioners at his back, actually worked at the formation of convenient ways from one village to another, and of a good and ready communication with the great road leading to Strasbourg. Besides his vast care of all his people's worldly concerns, he paid the greatest attention to moral and religious instruction. His sermons were simple, energetic, and affectionate, composed with great care, though plain and colloquial. His illustrations were drawn largely from objects in natural history, or in common life, with which the people were familiar. His discourses were often interspersed with anecdotes of persons distinguished for reverence of the Great Supreme. He cited largely from the Bible, for which he entertained the most devoted affection. He indulged in the common practice of the older divines, of drawing analogies between the natural and visible, and the spiritual world. But above all he loved to expatiate on the goodness of God, and the hopes, the promises, and the freeness of the gospel. For all denominations of Christians he had the widest toleration.

Such was Oberlin. Now look attentively at his portrait, and compare the height of the coronal region with those of Nero, Caracalla, and Pope Alexander VI.; then study the lives of the three last mentioned, as in history recorded, and then judge between them and Oberlin.

It is not possible for us to visit any country, whether civilized or savage, without being struck with the universal fact, that the inhabitants believe in and venerate a God. Pierre, in his "Studies of Nature," says—"Every nation has the sentiment of the existence of a God: not that they raise themselves to it as *Newton* or as *Socrates*, by the universal harmony of his works, but rather by fixing their attention on those blessings which interest them most. Thus, the Indians of Peru worship the sun; the Indians of Bengal, the Ganges, which fertilizes their fields. The black Jolof worships the Ocean, which cools his shores." Plutarch also coincides in the sentiment, that there is neither town nor village in the world without a god, and consequently there can be no people entirely destitute of a faculty which tends to reverence and worship.

If we consult the writings of the ancients, the sentiment is assented to by Aristotle, Cicero, Plato, Seneca, and others. There is no sentiment for which we have such abundant evidence as that under review. The Saviour of mankind and his apostles, particularly the beloved apostle, are represented with this portion of the brain very elevated. Melancthon and Fenelon are instances of it in the Roman Catholic Church. The late eminently learned and pious Bishop Heber in the English Church. The late eloquent Robert Hall among Dissenters; and the fervid and towering Chalmers in the Scottish Church. These names are in themselves a tower of strength; and if, where there is a similarity of organization, the same results are invariably perceived, who can doubt that a particular portion of the brain disposes to veneration and worship? The Church has at all times seen the necessity of exciting this organ, to induce a feeling of reverence in the mind of the worshipper. Whether we admire the gorgeous splendour attendant upon the ceremonies of the Romish Church, or turn to the cathedral services of the Episcopal Church, or even to the more sober and quiet ceremonial of the Presbyterian Church, they are all calculated to excite this organ, and intended to excite it. Charity appeals to it when an oratorio is to be performed, or when a sermon is to be preached by an eminent prelate, and the organ presided at by an eminent player. It is useful to stimulate it in a healthy manner; and when we show our love to God by the love we bear to each other, both Benevolence and Veneration are healthily exercised.

When the organ is too much exercised, unhealthily excited, and cultivated to excess, then it is indeed the source of intense suffering. There is nothing which has a greater tendency to brutify and debase the mind than superstition, and superstition is an abuse of the organ of Veneration. Reason, unenlightened by Revelation, seems to be incompetent to raise the thoughts and actions of men to purity; hence the world, under the moral darkness of heathenism, exhibits a mixture of ignorance and virtue. Even under the comparative civilization and refinement detailed in the better parts of the history of Greece and Rome, we have most deplorable instances of the depravity induced by diseased veneration. Socrates was condemned to death for supposed impiety, while the mild and, comparatively speaking, enlightened Trajan caused thousands of Christians to

suffer torments and death, for no other reason than that their religion was accounted an innovation.

Many persons have supposed that veneration always disposes to the worship of the Supreme Being; but experience has proved that though veneration always disposes to worship and respect, still a man may be largely endowed with the organ of Veneration, and yet be an infidel. The truth is, and melancholy it is to state it, there are as many, perhaps more, worshippers of self and the world, than of the Supreme Being. A vast number of persons worship the great—kings, for instance; among the most devout worshippers of this class was Voltaire. Some worship their wealth, their titles, their estates, their pictures, their statues, their books, their horses, their hounds, &c. Some worship their servants, as it is well known many servants worship their masters. We are acquainted with a strictly moral young man, a Deist, who told us that the object of his worship was Lord Brougham.

To those in whom the organ is strong, the word *old* is synonymous with *venerable*, and, in their view, no institution or doctrine, however hurtful or absurd, is, if sanctioned by antiquity, to be at all meddled with. They obstinately adhere to the religious tenets instilled into them in childhood, and will not listen to arguments to support doctrines of a contrary kind. When, on the other hand, the organ of Veneration is moderately developed, and the intellect acute and enlightened, the individual regards only the intrinsic merits of the doctrines and institutions which prevail around him, and shapes his opinions accordingly.*

The mere circumstance of antiquity is impressive to a character inclined to veneration. The Greek and Roman, when they became Christian, still clung fondly to the reminiscences of their early faith. The undying flame on Apollo's shrine reappeared in ever-lighted candles at the Roman Catholic altar; and the same idea that demanded vestal virgins for the heathen temple, set nuns apart for the Christian sanctuary. Tiara and embroidered garments were sacred to the imagination of the converted Jew, and conservatism, which in man's dual nature ever keeps innovation in check, led him to adopt them in his new worship. Thus did the spirituality of Christ come to us loaded with forms not naturally and spontaneously flowing therefrom. The very cathedrals, with their clustering columns and intertwining arches, were architectural models of the groves and high places sacred to the minds of the pagans, who from infancy had therein worshipped their strange gods. The days of the Christian week took the names of heathen deities, and statues of Venus were adored as Virgin mothers. The bronze image of St. Peter at Rome, whose toe has been kissed away by pious devotees, was once a statue of Jupiter. An English traveller took off his hat to it as Jupiter, and asked him, if he ever recovered his power, to reward the only individual who had ever bowed to him in adversity.

The reverential habit of mind varies its forms according to the temperament and character. The tendency betrays itself in the rainbow mysticism of Coleridge, the patriarchal tendencies of Wordsworth, and the divine aspirations of Beethoven.

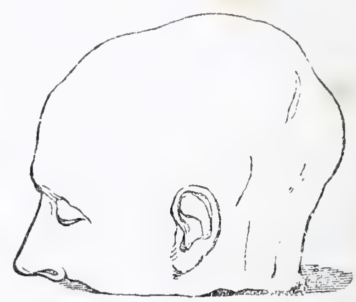
In some minds it is shown by a strong affection for everything antique. They worship shadowy legends, architectural ruins, and ancient customs. This habit of thought enabled Sir Walter Scott to conjure up the guardian spirit of the house of Avenal, and re-people the regal halls of Kenilworth. The works of Sir Walter Scott were the final efflorescence of feudal grandeur—that system had passed away from political forms, and no longer had a home in human reason, but it lingered with a dim glory in the imagination.

Another kind of minds rise to a higher plane of reverence. Their passion for the past becomes mingled with earnest aspirations for the holy—such persons walk in a golden fog of mysticism. To such, Puseyism comes forward like a fine old cathedral made visible by a gush of moonlight.

But be not disturbed by Pope or Pusey. They are but a part of the check and balance system of the universe, and in due time will yield to something better. Modes of faith last just as long as they are needed in the order of Providence, and not a day longer. *Truth* cannot be forced above its level, any more than its great prototype, *water*.*

God commands that we should love him, with *all* the heart, with *all* the soul, and with *all* the strength. But it must be obvious that there are very few of us who, in the true sense of the word, worship our God according to this sense. Our ruling love, instead of being fixed upon him, is fixed upon some other object, and, under whatever shape or whatever form our ruling love displays itself, we undoubtedly venerate and worship it. We may safely calculate the ruling love of an individual, if we can observe him in a picture gallery or a studio. A picture gallery is replete with character, where the living find their resemblances on the canvas. Some objects are beautiful, soft, and tender. Others are rude, harsh, and fierce. Some are delicate, pure, and chaste, others are directly the reverse. One picture exhibits revenge, another disposes to love. One excites terror; another, tenderness and compassion. Now, let an individual who wishes to study character, first go round the gallery or studio, and localize in his mind the different pictures or objects sculptured, and then let him observe their effects on the company, and we will venture to assert that those pictures or objects sculptured, on which the different spectators bestow the most attention, are, to the extent they reach, transcripts of their own mind; and these pictures they will dwell upon with fondness and veneration, proportioned to the intensity with which the predominant feelings are delineated. Go into a private house, even, and the pictures will index the mind of the owner. All this results from the dispositions and affections of man being differently affected by different organization. A man whose Veneration is large, and whose moral and religious sentiments harmonize, and who, at the same time, has small Combativeness and small Destructiveness, will feel the utmost abhorrence and disgust at scenes representative of war and bloodshed; while, on the contrary, he in whom this development is reversed, will feel the liveliest emotions of pleasure at the delineation of the battle-field.

15. Firmness.—The organ of Firmness is placed in the middle of the upper and posterior part of the sincipital region of the head, as in this portrait of M——:—



It is difficult to define this feeling. Its effects are often called *will*, and those who have it strong are prone to say, *I will;* but their will is not an act of reflection, a condition necessary to free-will and liberty. The meaning of their *I will* is—I desire, I command, I insist upon. This feeling contributes to maintain the activity of the other faculties, by giving perseverance and constancy. It also gives a love of independence; its too great activity produces stubbornness, obstinacy, and disobedience. Its deficiency renders man inconstant and changeable. Individuals so constituted have little determination, readily yield in their opinions, and are easily diverted from their pursuits or undertakings.

Lavater, in his "Physiognomy," remarked that persons endowed with firmness and perseverance have the top of the head much elevated. Dr. Gall has since confirmed this by many observations, and the organ is established.

We every day meet with persons of good abilities, but who, for want of perseverance and firmness, settle to nothing. Without decision of character, without moral firmness, man

* See Phrenological Journal, Vol. VIII.

* See "Letters from New York," by Mrs. Child.

becomes the butt of every other person's caprice or ill-humour. It has been observed by a celebrated writer on education, that we should never suffer our children to commence their worldly avocations until they can pronounce, with a manly assurance, the monosyllable "No."

There is no doubt but cultivation will strengthen any of the powers of the mind, and by the aid which Phrenology now offers, educators are put in possession of a key, by which they may most effectually train their pupils. We must have observed the difference in children's dispositions. Some children are very yielding, while others are stubborn and obstinate. To be possessed of the means whereby the former may be instructed in the necessity of firmness and perseverance, and the latter shown the unamiability of obstinacy, is surely highly important. For want of this knowledge, how frequently do we observe grown-up people, who can scarcely be said to have a will of their own. If such persons are benevolent, and have Love of Approbation large, you may ask what you will, and they will give it. They wish, but seem not to have the power, to say *nay*. On the other hand, take the man in whom this organ is of average power, and his conduct is firm and decided. A resolution once taken, he abides by it.

Where Firmness is associated with Combativeness, it produces the most determined bravery and perseverance. In Malcolm's "Persia" there is a fine illustration of this. There was no feature more remarkable in Timour, the great Asiatic conqueror, commonly known by the name of Tamerlane, than his extraordinary perseverance. No difficulties ever led him to recede from what he had undertaken, and he often persisted in his efforts under circumstances which led all around him to despair. On such occasions he used to relate to his friends an anecdote of his early life. "I once," he said, "was forced to take shelter from my enemies in a ruined building, where I sat alone many hours. Desiring to divert my mind from my hopeless condition, I fixed my eyes on an ant that was carrying a grain of corn, larger than itself, up a high wall. I numbered the efforts it made to accomplish this object. The grain fell *sixty-nine* times to the ground, but the insect persevered, and the seventieth time it reached the top. The sight gave me courage at the moment, and I never forgot the lesson."

In the person of the celebrated Joseph Hume, firmness may be stated as his distinguishing peculiarity—without it he could never have reached his present eminence. When he first went into Parliament, he stood almost alone as the advocate of economy and retrenchment. Hour after hour, when estimates were to be voted, he rose to propose reductions. He was assailed on all sides of the House by clamour. The members coughed, talked, crowed, and even, if report speaks truth, snored and brayed like asses, to put down Joseph Hume; but all proved fruitless—he persevered. Opposition and insult were equally fruitless; and the result is, his perseverance and honesty have at length secured him the respect of the House, and, in matters of finance, his sanction now carries considerable weight with it. There are others equally ardent in their wishes for economy, quite as desirous of retrenchment as he may be, but they want the power of brain which he possesses; above all, they want the inflexible firmness by which he is distinguished. Joseph Hume is a fine study for a phrenologist.

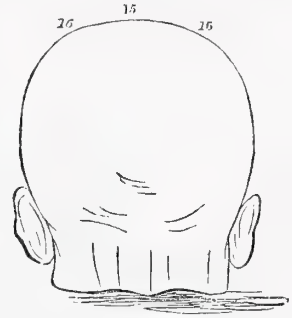
Firmness may be considered as one of the chief qualities of a good soldier. At the storming of the heights of Beira, on October 8, 1813, Colonel Colburne, who commanded the second brigade of Rifles, addressed the men as follows:—"Now, my lads, we'll just charge up the edge of the ditch, and if we can't get in, we'll stand there and fire in their faces." They charged accordingly, and the enemy fled from the works, and, in following them up the mountain, accompanied only by his brigade-major and a few riflemen, he found that he had headed a retiring body of about 300 of the French; and, whispering to his brigade-major to get as many men together as he could, he, without the least hesitation, boldly rode up to the enemy's commander and demanded his sword. The Frenchman surrendered with the usual grace of his countrymen, requesting the other that he would bear witness that he had conducted himself like a good and gallant soldier. Sir John answered the appeal with an approving nod, for it was no time to refuse bearing witness to the valour of 300 men, while they were in the act of surrendering to half-a-dozen. In this instance, the Colonel's firmness and presence of mind alone saved him.

The French are brave to a proverb;—it was not the superior bravery of the English that achieved so many victories, but their firmness and perseverance.

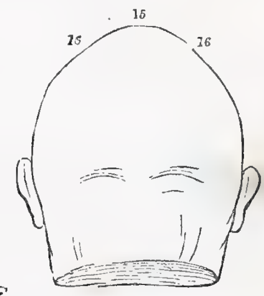
In every state of life, firmness is indispensable. Patience is one of the results of this faculty

When firmness is too energetic, its abuses are productive of much evil,—obstinacy, want of obedience to constituted authority, and the like.

16. Conscientiousness.—Conscientiousness is situated on each side of Firmness, just before Love of Approbation, on the posterior and lateral parts of the coronal surface of the brain. To Dr. Spurzheim may be attributed the honour of its discovery. He says,—"This faculty produces the feeling of duty, the desire of being just, and the love of truth. It looks for justice, and makes us wish to act justly, but it does not determine what is just or unjust. This determination depends on the combination of the sentiment with other affective and intellectual powers. He who unites Conscientiousness with active lower propensities, will call that just, which another, endowed with Conscientiousness, much Benevolence and Veneration,



15. Large Firmness.
16. Large Conscientiousness.



15. Large Firmness.
16. Small Conscientiousness.

and little of the lower propensities, calls unjust. 'All the ways of a man,' says Solomon, 'are clean in his own eyes, but the Lord weigheth the spirits.'

"This primitive feeling may be disagreeably affected in a way called repentance or remorse. Its great and general deficiency among mankind is much to be lamented; it is this that occasions, as it explains, the many unprincipled acts that are continually done."

Without Conscientiousness, man would degenerate into a savage, or follow what Sir Walter Scott has so ironically described—

> "The good old plan,
> That they should take who had the power,
> And they should keep who can."

Conscientiousness restrains this, and insists upon doing to our neighbour as we would our neighbour should do to us. This sentiment is by phrenologists considered as the prime regulating power of the whole brain, and ought to be most carefully and attentively cultivated. There are some who contend that it is not innate, but acquired. There can be no doubt that all the powers of the mind are innate; but, from neglect, many, and this especially, have become less active in their functions than the others. The more an organ is exercised, the more energetic does it become; and Conscientiousness, were it constantly exercised in all and every case, would speedily bring man to a state of moral purity. In those persons in whom it is largely developed, it may with truth be said to behave itself wisely in a perfect way. It is, in such case, undoubtedly the prime regulating power of the whole brain, and may be said to exercise itself in a vigilant superintendence over the others, and preventing them from degenerating into abuse:—Do any of the lower propensities seek an indulgence of their respective functions, Conscientiousness at once interposes to prevent the sin. Does Combativeness rise up and crave the exercise of its quarrelsome or litigious functions, Conscientiousness keeps it

in subjection: it seems to interpose a check, in some such language as,—Obtain your right; defend yourself against aggression, but I permit no aggression. Or does Acquisitiveness grasp at more than strict justice will allow, Conscientiousness raises its baton, and bids us respect the rights of others. Or does Benevolence appear about to lose its legitimate functions, and threaten to degenerate into profusion and prodigality, without distinction of person or object—about to bestow upon the whining worthless, that which would ameliorate the condition of the suffering and the miserable? Be just, says conscience; seek out those objects whose necessity is great, but whose modesty prevents their thrusting their claims prominently into notice.

In illustrating the deficiency of this organ, we cannot help adverting to one common practice which unhappily distinguishes the present age.

While, in some places, more especially where ignorance gives scope to rapacity, it is the custom to do the best possible for *self*, by charging as much as possible for articles of trade; in others, especially where the buyer knows as well as the seller the cost of production, it is usual to charge the least possible price to conciliate his favour. Hence ensues a sad contest. The labourer is gradually pinched almost out of existence, to support the bulky exterior of glittering poverty consequent upon this system, which is found in the warehouse of the manufacturer.

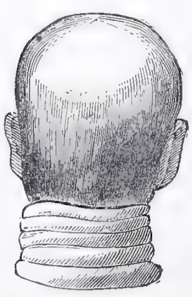
"Let us," thus runs the short-sighted cant of the counter—(the wholly deficient in Conscientiousness)—"sell for next to nothing, or even really for nothing; yea, at a dead loss for a time, that we may run off our opponents, gain the confidence of customers, and establish us a name." A name! for what? "*For* CHEAPNESS." FOR CHEAPNESS! Pray, what virtue does cheapness represent? Is it conscience? Is it liberality? Are we desirous, by a cheapness which sacrifices living profit, and which ruins the small capitalist dealing in similar goods, to obtain the reputation of being spiritedly liberal? "Regardless of large gains!—above the love of amassing a fortune!" Is this our end? There is somewhat of life—true life, in such a disposition, but it belongs not to the abettors of the system we are deprecating. A name for liberality so acquired is in the mouths of some a falsehood, and of others something worse, if that be possible. The end is the all in all of the means, and that end is but too clearly stated in the words, *to run off our opponents:* in plain terms, defraud and starve their neighbours—keep down the sentiment of conscience, in order that greater gain may accrue to themselves. This spirit is the spirit of covetousness, and the spirit of covetousness is the fountain of theft. We think it would not require a lengthy argument to prove, and yet it requires courage to write it down, that every tradesman who, in a regular way, and for the purpose of running off his opponents, sells his goods, or peculiar portions of them, without profit, is destitute of a real principle of conscience.

Mr. Combe, in his "Moral Philosophy," gives us the following case:—"I knew an individual in the situation of a confidential clerk, who had a good intellect, with much Benevolence, Veneration, and Love of Approbation, but in whom a large organ of Secretiveness was combined with deficient Conscientiousness. His life had been respectable for many years in the situation of a clerk, while his duty was merely to write books and conduct correspondence. But when he was promoted, and intrusted with buying and selling, and paying and receiving cash, his moral principles gave way. And the temptation to which he yielded was not a selfish one. He was much devoted to religion, and began by lending his master's money for a few days to his religious friends, who did not always pay him back. He then proceeded to assist the poorer brethren with it. He next opened his house in great hospitality to the members of the congregation to which he belonged. These expenses speedily placed his cash so extensively in arrear, that he had no hope of recovering that deficiency by any ordinary means, and he then purchased *lottery tickets* to a large amount, trusting to a good prize for his restoration to honour and independence. These prizes never came, and the result was disclosure, disgrace, and misery."

Covetousness results from the large development of Acquisitiveness, unrestrained by the higher sentiments of justice, benevolence, and the powers of reflection; and this covetousness, grasping at the gold which tends to gratify its cupidity, has caused the most direful crimes; and doubtless it was the mainspring of the crime which instigated the murderer Rush, and whose cupidity and want of Conscientiousness has only been equalled by his unbending obstinacy, and simulated by his cunning and duplicity. Indeed, unrestrained Acquisitiveness may be said to be at the root of all crime, as it is at the root of all evil. War springs up from its unbridled exercise, and pillage and blood follow in its train. It has banished religion from the soul; it has blunted and destroyed parental feeling; it has frozen the current of connubial affection; it has cut asunder the holiest ties of friendship; it has served as an Upas, to shed its withering shade over the human family. It renders a once happy nation miserable, and transforms its rulers into a nest of stern exactors, who, like the daughters of the horse-leech, are continually crying—Give, give! Nor is this bane of everything that is good confined to one class of the human family. It seems to have permeated all grades of society, and money has become the standard of respectability. It has surrounded the throne with its magic and corrupting circle. It has entered churches, and mitred heads have bowed before its debasing power. It has become a moral pestilence, and has extended its baneful influence in every direction, and the golden calf is set up and worshipped as the universal god. From the throne to the coronet, from the coronet to the church, from the church to the man of the world, the railway speculator, and even to the poorest among us—the earnest plea is not for friendship, for virtuous love, for cultivated intellect, for conscience, for tenderness and benevolence of soul, but—FOR GOLD.

This covetousness and love of gold has supplanted in the breast of man the love of his Saviour. This mammon has usurped in men's hearts the throne of Deity itself. Foreign battle-fields, running with rivers of human blood, attest its desolating power. The perpetrators of which atrocities so stimulated are heroes, but the perpetrator, by a similar impulse of one or more victims, is a murderer. Give honours, titles, decorations to the former, and suspend from the gallows-tree the latter. How great, then, is the need for the cultivation of Conscientiousness to restrain these evils!

In Sir Walter Scott's tale of the "Heart of Mid-Lothian," this faculty is most beautifully delineated. In her we behold what the love of truth can accomplish—she dared not to lie even to save a sister's life. The power of conscience is exemplified in different individuals by every-day observation. Scarcely a day passes, but the Chancellor of the Exchequer receives large sums for conscience-money. In David Haggart, the organ of Conscientiousness is deficient, while Firmness is large. In the Rev. Mr. M——, on the contrary, Conscientiousness is beautifully developed, and Firmness is also good—as in the following cuts:—



"The difference of this organ in different nations and individuals," says Mr. Combe, "and its combinations with other organs, enable us to account for the differences in the notions of justice entertained at different times by different people. The sentiment of truth is found by the English judges to be so low in the Africans, the Hindoos, and by the aboriginal Ameri-

LEIGH'S PATENT SELF-STRIPPING ENGINE.

Fig. 1.

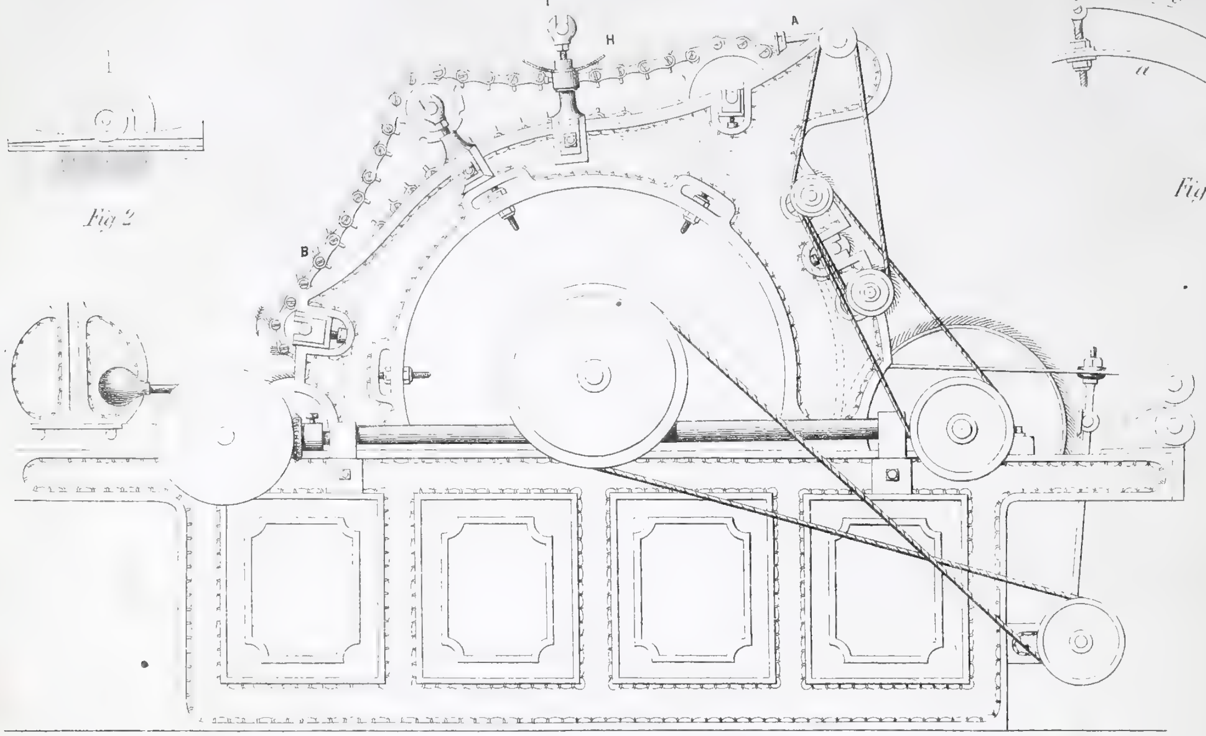


Fig. 2

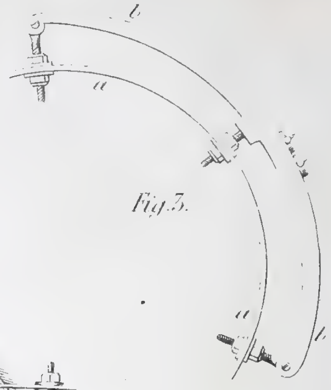
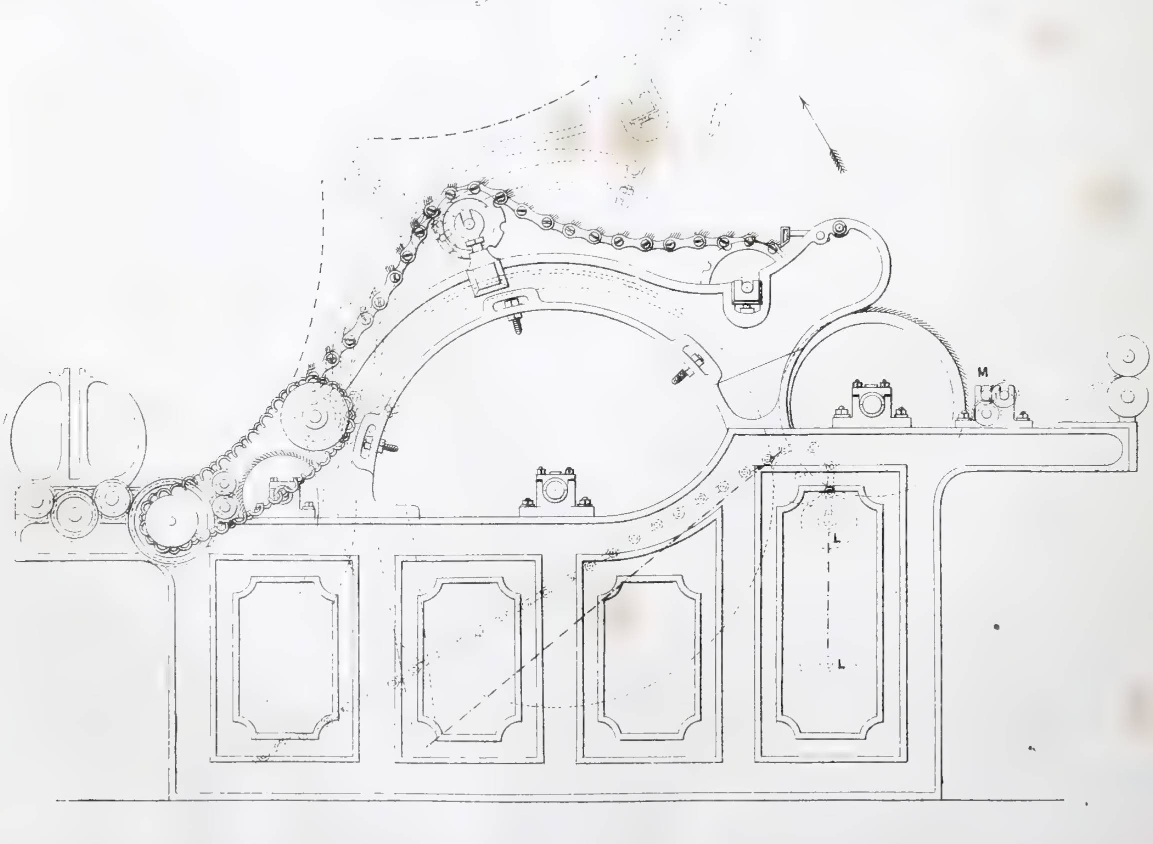


Fig. 3.

Fig. 4



cans, that the natives of those countries are not received as witnesses in the colonial courts; and it is a curious fact, that the reigning feature of the skulls of these nations, now in possession of the Phrenological Society, is a deficiency in the organ of Conscientiousness."

THE MACHINERY OF THE COTTON MANUFACTURE.

CHAPTER III.

CARDING ENGINE AND DRAWING FRAME.

We now proceed to describe the operation of the next machine —the "carding engine." The fibres of the cotton, after passing from the blower, are laid in all directions one to another. In order to enable a continuous "thread" to be made of them, it is essential that all the fibres shall lie in one direction, that is, parallel to one another. The better this operation is conducted, the better will be the quality of the thread or yarn spun. It is to effect this parallelization of fibre, that what are called the "machines of preparation"—namely, the "carding engine" and the "drawing frame"—are used. The first degree of parallelization, the carding engine effects. How it is performed we shall now endeavour to describe.

The operation of carding is similar in principle to combing. Thus, if a few fibres of cotton, lying in all imaginable directions, be repeatedly combed between the teeth of two combs, or between the bristles of two hard brushes, the fibres will ultimately be made to lie all in one direction. This operation is effected by the "carding surfaces" of the carding engine. The teeth of the combs or cards are made in the form shown in fig. 23. The ends, *b*, *b*, are turned at angles to *a*; *c*, *c*, being placed at a determinate angle to *b*, *b*. They are arranged in strips of leather, as at *b b*, fig. 24. The operation of carding by these teeth, or carding surfaces, is as follows:—If a few fibres of cotton are placed between them, and the carding teeth moved in opposite directions —the directions of the teeth being different—the teeth of one will pull the fibres in one direction, the teeth of the other will pull some other fibres in an opposite direction. The result of this arrangement will be, that the fibres will ultimately be placed parallel to one another. Suppose further, that the teeth of both the upper and under cards are lying in one direction, and that the cards both move in one direction, but one card with a greater velocity than the other, the result will be, that while the parallelization is being carried on as before, the card having the greatest velocity will strip the cotton from off the card moving the slowest.

Fig. 23.

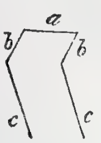


Fig. 24.

We are now prepared to enter into the minutiæ of the arrangements of the carding engine.

The strips of leather containing the card teeth, are fastened in parallel rows on the periphery of a large cylinder, as *a a*, fig. 25. This cylinder, in some instances, is composed of parallel segments of mahogany; but the improved method is by having at the periphery of the cylinder parallel strips of baywood, the spaces being filled with cement, in which white lead is the principal ingredient. When this is hardened, the cylinder is put into a lathe, and the outer surface faced up "true." Around the large cylinder, *a a*, fig. 25, smaller ones, *b b*, are placed, having on their periphery spiral strips of card fillets. These small cylinders are termed "urchins" or "squirrels," but more frequently "strippers" and "clearers," as their office is to strip off the cotton from the large cylinder, and redeliver it. The slow-moving cylinders hold the cotton, while the quick-revolving cylinder cards it out. In carding engines for low counts or coarse yarn, the carding is entirely performed by means of the large cylinder and the strippers or clearers. In the Plate Carding Engine (section), we show the arrangement of the carding engine introduced by Mr. Mason of Rochdale for "medium numbers." We give also a side elevation of this, showing the gearing and method of communicating motion to the carding cylinders. The lap-roller is placed in the slotted bearings at *a a*. The lap is unwound from this, taken up by the feed-roller, *b b*, from thence taken by the "licker-in," *c c*, and delivered to the main cylinder, *d d*. From this it is taken up by the stripper, *f*, and redelivered to the main cylinder, *d d*. The operation is thus repeated; the various strippers, *g*, *h*, *i*, *m*, *n*, *o*, *p*, *q*, *r*, and *s*, taking up and redelivering the cotton to the main cylinder. In this way the fibres become arranged parallel to one another on the surface of the main cylinder, *d d*. They are then taken off by the "doffer cylinder," *t t*, on the periphery of which the cards are arranged in spiral rows. The fleece of cotton wool is taken off the surface of the doffer cylinder by means of the "doffer knife," *u*. The lower edge of this is toothed like a comb, and has a quick up-and-down motion

Fig. 25.

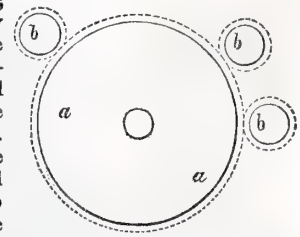


Fig. 26.

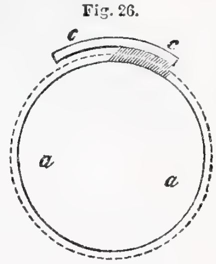
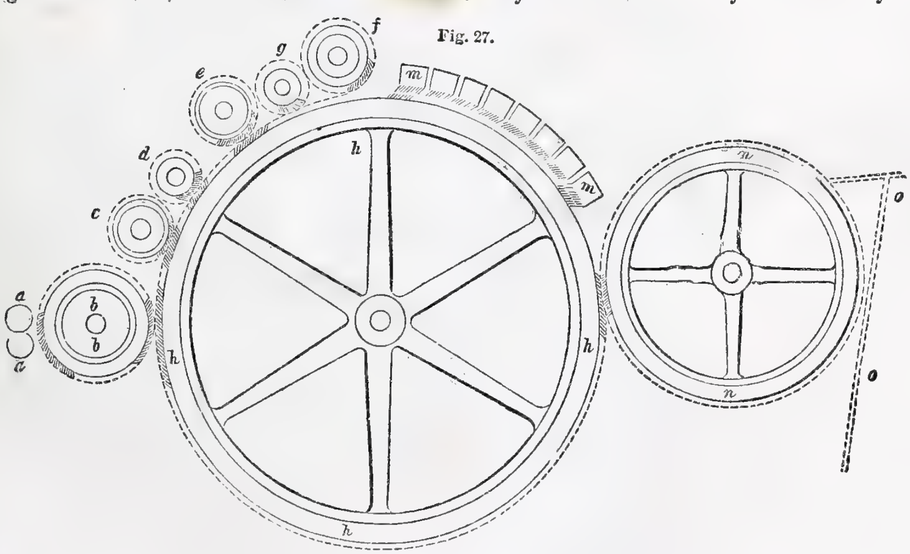
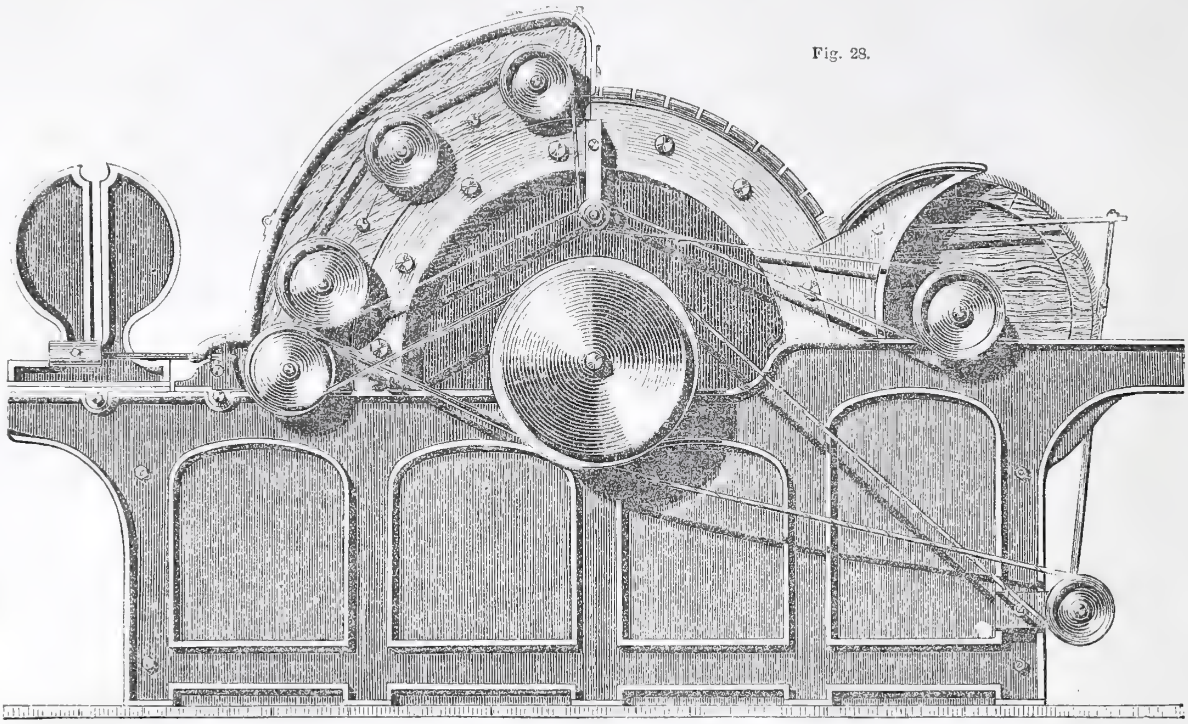


Fig. 27.



imparted to it by the crank, *v*, and shaft. There are two kinds of carding engines—"breaker" and "finisher" cards. In the former, the fleece, after being stripped from off the doffer cylinder, is wound round a lap-roller, and passed through the operation of carding a second time. In the latter, the fleece, after being stripped from the doffer, is passed through a trumpet

Fig. 28.



mouth, *x*, and through a series of rollers, and finally delivered to the tall tin can 2.

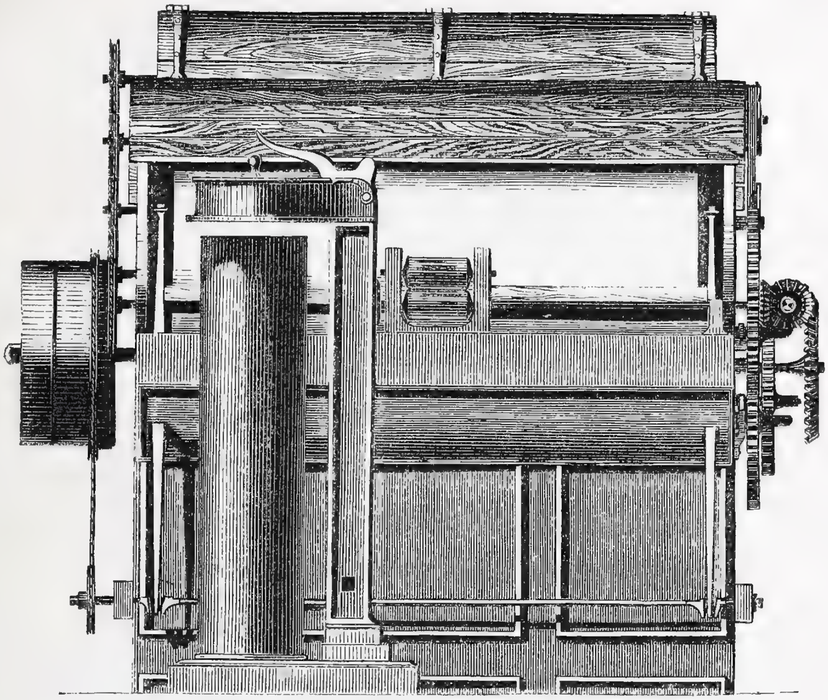
In some carding engines, flat top cards are used, and are termed "flats." The arrangement of these is shown in the diagram, fig. 26, where they are shown at *c c*, the card teeth of the main aylinder sweeping over the surface. As a

Fig. 29.

general rule, the higher the "counts," or the finer the yarn to be spun, the more flats are used. In fig. 27 we give a diagram illustrative of the arrangements of a carding engine, in which the system of having rollers, strippers, and flats is used. The lap-roller is inserted in the slots. The cotton is taken up by the feed-rollers, *a*, *a*, and caught up by the

licker-in, *b b*. From this it is taken up by the main cylinder, *h h*, from which it is taken up by the roller or stripper, *c*. Taken up by *d*, it is again delivered to the main cylinder, which delivers it to *e*, which in its turn is stripped by *g* and *f*, and from *f* taken up again by the main cylinder. The flats, *m*, *m*, hold the wool, which is carded and taken off them by the main cylinder. The fleece is finally taken up by the doffing cylinder, *n n*, being stripped from this by the doffer knife, *o o*, and finally

Fig. 30.



passed through the trumpet mouth, *p p*, and delivered to the can. In fig. 28 we give an elevation of the carding engine (of which fig. 27 is a part section), at that side at which the driving pulleys are placed. Fig. 29 is a side elevation, showing the toothed gearing, and fig. 30 an end elevation at delivering end, of the same engine as in fig. 28.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING: THE CALOTYPE, DAGUERROTYPE, &c.

CHAPTER IX.

THE WET METHOD ON PAPER—MISCELLANEOUS PROCESSES WITHOUT THE SALTS OF SILVER—MR. TALBOT'S INSTANTANEOUS PROCESS ON GLASS—THE HELIOCHROME, OR COLOURED PHOTOGRAPHS.

Having given somewhat minutely, in last chapter, the details of M. Le Gray's "dry method" on paper, from the first operation of waxing the paper for the negative proof to the finishing and fixing of the positive, we must subjoin, from the same writer, a short account of his "wet method," to render our summary of these processes complete. For this purpose let us revert to the third operation stated in describing the dry method, and let us suppose that the solution of aceto-nitrate of silver, prepared according to either of the formulas given under that head, has been prepared by the operator. It must also be assumed that the paper, with or without waxing, has been iodized as directed in process No. 2.

Then, to operate by the wet method, a little of one of the aceto-nitrate solutions (No. 3) is poured upon a porcelain or glass tablet, and over the surface of the liquid a piece of white paper is passed to draw off any impurities. A sheet of iodized paper is then taken by the two corners, and placed with the prepared side upon the aceto-nitrate, raising and lowering it several times to expel the air bubbles. A palette knife may be used in this operation, to avoid staining the fingers with the nitrate. The paper is allowed to remain on the solution from one to five minutes, taking the greatest care that none of the aceto-nitrate get upon the back of the paper. The time required depends on the temperature and quality of the paper; when waxed, it will take from four to five minutes. The paper, thus prepared, is applied quite moist upon a slate, upon which you have previously stretched, to receive it, a sheet of unsized paper well saturated with water. As a matter of course, the prepared side must be outwards. "The paper so placed," says M. Le Gray, "may remain for three or four hours, without loosening or becoming injured for use in the camera. When I am going far to take a picture, I steep the first sheet in gum water, which retains the humidity longer, and is more adherent. You may make use of two glasses between which to place the prepared paper, but great precaution must be taken to keep the glasses very clean."

Iodizing a paper for portraits.—The following are given as the best proportions in iodizing a paper specially for portraits:—

Distilled water,..............................	6½	ounces.
Iodide potassium,..............................	160	grains.
Cyanide do.,..............................	16	do.
Fluoride do.,..............................	4	do.

This solution is poured into a flat porcelain dish, and the paper is placed upon it for one or two minutes, after which it is thoroughly dried between sheets of very fine blotting paper. It is then placed with the prepared side upon the bath of nitrate of silver (the first formula given in the third operation), where it is left eight or ten seconds at most, and immediately placed upon the slate or glass of the camera, which has been previously covered, as already stated, with a sheet of blotting paper well saturated with water. This paper must be used

immediately, because its great sensibility depends chiefly upon the commencement of the formation of the iodide of silver. In summer four to ten seconds of exposure in the shade, and in winter eighteen to forty seconds, will be sufficient for a portrait.

MISCELLANEOUS PROCESSES ON PAPER WITHOUT THE SALTS OF SILVER.

It will have been remarked, that in all the processes described in the preceding chapters—whether on glass, daguerreotype plates, or paper—the chloride or iodide of silver forms the principal ingredient in producing the sensitive surface. It would, however, be quite a mistake to suppose that the compounds of silver alone are sensitive to the action of light. On the contrary, almost all substances, both organic and mineral, seem, from recent photographic researches, and more especially from those of Sir John Herschel, to be, in a greater or less degree, subject to the decomposing influence of this mysterious agent—that is to say, of the *actinic* element in light. As we do not pretend to exhaust the scientific part of the subject in these chapters, it would not be consistent with our plan to enumerate the various interesting experiments by which this important truth has been established, and for which we are chiefly indebted to the zeal of photographic inquirers. There are, however, a few processes to which specific names have been given, and which may be successfully practised by the amateur, while, at the same time, they will be so far sufficient to show that the salts of silver are not essential to photography. It must be admitted, indeed, that, with one or two exceptions, preparations in which silver is dispensed with, have not hitherto been rendered sufficiently sensitive for operation with the camera, and therefore they have not superseded in general practice the ordinary processes which have been already described. Most of them, however, are interesting as contributions to science, and some of them may lend a pleasing variety even to the practical manipulations of the artist. Our treatise would, therefore, be incomplete without a brief enumeration of some of the more successful and practically useful examples of these miscellaneous processes. We shall begin with

The Cyanotype.—This term is applied to those processes in which cyanogen is employed, and for which the scientific world is indebted to Sir John Herschel. They admit of considerable variety; but two of the results will be sufficient to illustrate the agency employed, and these we shall give in the words of Sir John Herschel himself:—

"There can be no doubt," he says, "that the (photographic) process, in a great majority, if not in all cases, which have been noticed among inorganic substances, is a deoxidizing one, so far as the more refrangible rays are concerned. A beautiful example of such deoxidizing action on a non-argentine compound, has lately occurred to me in the examination of that interesting salt, the ferrosesquicyanuret of potassium, described by Mr. Smee in the Philosophical Magazine, No. 109, September, 1840, and which he has shown how to manufacture in abundance and purity, by voltaic action on the common or yellow ferrocyanuret. Paper simply washed with a solution of this salt is highly sensitive to the action of light. Prussian blue is deposited (the base being necessarily supplied by the destruction of one portion of the acid, and the acid by decomposition of another). After half an hour or an hour's exposure to sunshine, a very beautiful negative photograph is the result, to fix which, all that is necessary is to soak it in water, in which a little sulphate of soda is dissolved, to insure the fixity of the prussian blue deposited. While dry, the impression is dove-colour or lavender-blue, which has a curious and striking effect on the greenish-yellow ground of the paper, produced by the saline solution. After washing, the ground colour disappears, and the photograph becomes bright blue on a white ground. If too long exposed, it gets 'over-sunned,' and the tint has a brownish or yellow tendency, which, however, is removed in fixing; but no increase of intensity beyond a certain point is obtained by continuance of exposure."

Sir John remarks, that the "varieties of cyanotype processes seem to be innumerable." The following is another of these processes, with which we must be satisfied for the present.

"If paper be washed with a solution of ammonio-citrate of iron, and dried, and then a wash passed over it of the yellow ferrocyanuret of potassium, there is no immediate formation of true prussian blue, but the paper rapidly acquires a violet-purple colour, which deepens after a few minutes, as it dries, to almost absolute blackness. In this state, it is a positive photographic paper of high sensibility, and gives pictures of great depth and sharpness—but with this peculiarity, that they darken again spontaneously on exposure to the air in darkness, and are soon obliterated. The paper, however, remains susceptible to light, and capable of receiving other pictures, which in their turn fade, without any possibility (so far as I can see) of arresting them; which is to be regretted, as they are very beautiful, and the paper of such easy preparation. If washed with ammonia or its carbonate, they are for a few moments entirely obliterated, *but presently reappear with reversed lights and shades.* In this state they are fixed, and the ammonia, with all that it will dissolve, being removed by washing in water, their colour becomes a pure prussian blue, which deepens much by keeping."

The Chrysotype.—This term, which signifies a picture formed with gold, is another of Sir John Herschel's processes, and is described by him as follows:—"Paper is to be washed with a moderately concentrated solution of ammonio-citrate of iron, and dried. The strength of the solution should be such as to dry into a good yellow colour, not at all brown. In this state it is ready to receive a photographic image, which may be impressed on it either from nature in the camera obscura, or from an engraving on a frame in sunshine. The image so impressed, however, is very faint, and sometimes hardly perceptible. The moment it is removed from the frame or camera, it must be washed over with a neutral solution of gold, of such strength as to have about the colour of sherry wine. Instantly the picture appears, not indeed, at once, of its full intensity, but darkening with great rapidity up to a certain point, depending on the strength of the solutions used, &c. At this point nothing can surpass the sharpness and perfection of detail of the resulting photograph. To arrest this process, and to fix the picture (so far at least as the further agency of *light* is concerned), it is to be thrown into water, very slightly acidulated with sulphuric acid, and well soaked, dried, washed with hydrobromate of potash, rinsed, and dried again. Such is the outline of a process to which I propose applying the name of *Chrysotype*, in order to recall, by similarity of structure and termination, the *Calotype* process of Mr. Talbot, to which, in its general effect, it affords so close a parallel."

The Chromatype.—This process was devised by Prof. Hunt: it is exceedingly simple in its manipulation, and produces very pleasing positive pictures by the first application. The following are the author's details of the process:—One drachm of sulphate of copper is dissolved in an ounce of distilled water, to which is added half an ounce of a saturated solution of bichromate of potash; this solution is applied to the surface of the paper, and when dry, it is fit for use, and may be kept for any length of time without spoiling. When exposed to sunshine, the first change is to a dull brown, and if checked in this stage of the process we get a negative picture, but if the action of the light is continued, the browning gives way, and we have a positive yellow picture on a white ground. In either case, if the paper, when removed from the sunshine, is washed over with a solution of nitrate of silver, a very beautiful positive picture results. In practice, it will be found advantageous to allow the bleaching action to go on to some extent; the picture resulting from this will be clearer and more defined than that which is procured when the action is checked at the brown stage. To fix these pictures, it is necessary to remove the nitrate of silver, which is done by washing in *pure* water; if the water contains any muriates, the picture suffers, and long soaking in such water obliterates it, or if a few grains of common salt are added to the water, the apparent destruction is very rapid. The picture is, however, capable of restoration—all that is necessary being to expose it to sunshine for a quarter of a hour, when it revives; but instead of being of a red colour, it becomes lilac, the shades of colour depending upon the quantity of salt used to decompose the chromate of silver which forms the shadow parts of the picture.

If sulphate of nickel be substituted for the sulphate of copper, the paper is more sensitive, and the picture is more clearly developed by nitrate of silver. If the chromate of copper is dissolved in ammonia, a beautiful green solution results, and if applied to paper they act similarly to those just described.

"Paper prepared with the bichromate of potash," says Mr. Hunt, "though as sensitive as some of the papers prepared with the salts of silver, is much inferior to most of them, and is not sufficiently sensitive for the camera obscura. This paper, however, answers quite well for taking drawings from dried plants, or for copying prints. Its great recommendation is its cheapness, and the facility with which it can be prepared. The price of the bichromate of potash is about two shillings per pound, whilst the nitrate of silver is five shillings the ounce."

WITH SALTS OF SILVER.

The Energiatype, or Ferrotype.—This process, which is of remarkable sensibility, was likewise discovered by Professor Hunt. It affords excellent pictures by the camera, but it will be seen that the nitrate of silver is one of the ingredients employed in preparing the paper. The process was published by the author in the *Athenæum*, and is as follows:—Good letter paper (Whatman's is the best) is washed over with the following solutions, viz.: five grains of succinic acid dissolved in one fluid ounce of water, to which is added about five grains of common salt, and half a drachm of mucilage of gum-arabic. The succinic must be obtained free from any oil of amber or adventitious matter. When dry, the paper is drawn over the surface of a solution of sixty grains of nitrate of silver in one ounce of distilled water. Allowed to dry in the dark, it is then fit for use, is of a pure white, retains its colour, and may be preserved for a considerable time in a portfolio, until wanted for use. Extreme care must be taken, however, that the paper be excluded from light, after applying the nitrate of silver, until it is about to be used; for though no immediate apparent effect may be produced, the clearness of the subsequent picture will be materially injured by exposure to light at this part of the process. When placed in the camera, an exposure for half a minute in strong sunshine is usually sufficient for a building; two or three minutes are required for a portrait, which can only be taken in the shade. To develop the picture, which, when taken from the camera, is quite invisible, mix together about one drachm of a saturated solution of *protosulphate of iron*, and two or three drachms *mucilage of gum-arabic*, pour a small quantity into a flat dish, and pass the prepared side of the paper over the mixture, taking the usual precautions that the iron solution does not touch the back of the picture. When the image appears, which will generally take place almost immediately, the further action of the iron must be stopped by the application of a soft sponge and plenty of clean water. When carefully washed to take off any superficial blackness, the picture is permanently fixed by being soaked in water, to which has been added a small quantity of ammonia, or, better still, hyposulphate of soda. It is then again well washed in clean water, to remove the soluble salts, and may then be dried and pressed. Positive pictures are procured from the negative proofs, by preparing the paper according to the same process, and exposing to the action of light in the copying frame; but, instead of using the iron solution, the paper is exposed in the light in the frame a sufficient time to obtain perfect copies. The positives are then fixed, like the negatives, with hyposulphite. It is scarcely needful to add, that the *ferrotype* is so called from the use of a salt of iron in developing the image; the name *energiatype* is, we presume, applied to the same process from the rapidity of its action.

The Fluorotype is so called from the introduction of the salts of fluoric acid, but the nitrate of silver is used in this process also. It consists of the following operations:—Dissolve in one fluid ounce of distilled water, 26 grains of bromide of potassium; in another ounce of distilled water dissolve five grains of fluate of soda. When the papers are about to be prepared, mix together a small quantity of these solutions, and wash the papers once over with the mixture. When dry, apply a solution of nitrate of silver, sixty grains to the ounce of water. The papers thus prepared will keep good for some weeks, and the image will be obtained in the camera in half a minute. When removed from the camera, the impression is not sufficiently strong for producing positive pictures; but may be rendered so by the following process:—Soak the photograph in water for a few minutes, and then place it on a porcelain slab, and brush over it a weak solution of the protosulphate of iron. The picture will almost immediately acquire an intense colour, which should then be stopped directly by plunging it into water slightly acidulated with muriatic acid, otherwise the blackening will extend all over the paper. It is fixed by being soaked in water, then dipped into a solution of hyposulphite of soda, and again soaked in water as in the other processes. The effect is improved by adding to the protosulphate of iron a little acetic or sulphuric acid, which is found to prevent, to a great extent, the darkening of the lights of the picture.

The Catalysotype.—This process, which is capable of producing pictures of very great excellence, was discovered by Dr. Woods, and is thus described by the inventor:—Let well-glazed paper (he prefers that called wove post) be steeped in water, to which hydrochloric acid has been added in the proportion of two drops to three ounces. When well wet, let it be washed over with a mixture of sirup of ioduret of iron, half a a drachm, water two drachms and a half, tincture of iodine one drop. When this has remained on the paper for a few minutes, so as to be imbibed, dry it lightly with bibulous paper, and, being removed to a dark room, let it be washed over evenly, by means of a camel-hair pencil, with a solution of nitrate of silver, ten grains to the ounce of distilled water. The paper is now ready for the camera; and the sooner it is used the better, as, when the ingredients are not rightly mixed, it is liable to spoil by keeping. The time I generally allow the paper to be exposed in the camera, varies from two to thirty seconds; in clear weather, without sunshine, the medium is about fifteen seconds. With a bright light, the picture obtained is of a rich brown colour; with a faint light, or a bright light for a very short time continued, it is black. For portraits out of doors, in the shade on a clear day, the time for sitting is from ten to fifteen seconds. When the paper is removed from the camera no picture is visible; however, when left in the dark, without any other preparation being used, for a period which varies with the length of time it was exposed, and the strength of the light, a negative picture becomes gradually developed, until it arrives at a state of perfection which is not attained, I think, by photography produced by any other process. It would seem as if the salt of silver, being slightly affected by the light, though not in a degree to produce any visible effect on it if alone, sets up a catalytic action, which is extended to the salts of iron, and which continues after the stimulus of the light is withdrawn. The catalysis [or *dissolution*] which then takes place, has induced me to name this process, for want of a better word, the catalysotype. It may be added, that the picture, when developed, though not readily injured by exposure to moderate light, should be fixed by washing it with a solution of bromide of potassium, fifteen or twenty grains to the ounce, or iodide of potassium, five grains to the ounce, applied either with a camel-hair pencil or by immersion. The picture must then be well washed in water to remove the fixing material, which would cause it to fade by exposure to light.

MR. TALBOT'S INSTANTANEOUS PROCESS.

We have seen that, in the process on glass with collodion, when properly managed, the image is so rapidly impressed that the cap of the camera lens may be opened and shut again immediately. The action in this case may, therefore, be considered instantaneous; and reference has already been made to the opinion of M. Le Gray, in describing his method with albumen on paper, "that the image is formed from the first moment that the luminous rays transmitted from the object lens strike the sensitive paper." Indeed, it is a well-supported opinion, that the action of the light is in all cases instantaneous, although, when the exposure has been short, the development

is generally more tardy, and sometimes cannot be effected by any reactive agent yet discovered. To Mr. Talbot, however, belongs the triumph of having devised a process which he has practically proved to be instantaneous, by obtaining a photographic picture of a printed paper fixed upon a wheel, while the latter was made to revolve as rapidly as possible, and suddenly illuminated by an electric spark. This experiment was shown several months before the publication of the process by which the result was effected; but at length the process was communicated by Mr. Talbot to the *Athenæum* of Dec. 6, 1851, from which we subjoin the details in the discoverer's own words:—

"1. Take the most liquid portion of the white of an egg, rejecting the rest. Mix it with an equal quantity of water. Spread it very evenly upon a plate of glass, and dry it at the fire. A strong heat may be used without injuring the plate. The film of dried albumen ought to be uniform, and nearly invisible.

"2. To an aqueous solution of nitrate of silver, add a considerable quantity of alcohol, so that an ounce of the mixture may contain three grains of the nitrate. I have tried various proportions, from one to six grains, but perhaps three grains answer best. More experiments are here required, since the results are much influenced by this part of the process.

"3. Dip the plate into the solution, and then let it dry spontaneously. Faint prismatic colours will be seen upon the plate. It is important to remark, that the nitrate of silver appears to form a new chemical combination with the albumen, rendering it much harder, and insoluble in liquids which dissolved it previously.

"4. Wash with distilled water, to remove any superfluous portions of the nitrate of silver. Then give the plate a second coating of albumen similar to the first; but in drying it, avoid heating it too much, which would cause a commencement of decomposition of the silver. I have endeavoured to dispense with the operation No. 4, as it is not so easy to give a perfectly uniform coating of albumen as in No. 1. But the inferiority of the results obtained without it, induces me for the present to consider it as necessary.

"5. To an aqueous solution of protiodide of iron, add first an equal volume of acetic acid, and then ten volumes of alcohol. Allow the mixture to repose two or three days. At the end of that time it will have changed colour, and the odour of acetic acid as well as that of alcohol will have disappeared, and the liquid will have acquired a peculiar but agreeable vinous odour. It is in this state that I prefer to employ it.

"6. Into the iodide thus prepared and modified, the plate is dipped for a few seconds. All these operations may be performed by moderate daylight, avoiding, however, the direct solar rays.

"7. A solution is made of nitrate of silver, containing about seventy grains to one ounce of water. To three parts of this, add two of acetic acid. Then, if the prepared plate is rapidly dipped once or twice into this solution, it acquires a very great degree of sensibility, and it ought then to be placed in the camera without much delay.

"8. The plate is withdrawn from the camera, and, in order to bring out the image, it is dipped into a solution of protosulphate of iron, containing one part of the saturated solution diluted with two or three parts of water. The image appears very rapidly.

"9. Having washed the plate with water, it is now placed in a solution of hyposulphite of soda, which, in about a minute, causes the image to brighten up exceedingly, by removing a kind of veil which previously covered it.

"The plate is then washed with distilled water, and the process is terminated. In order, however, to guard against future accidents, it is well to give the picture another coating of albumen or of varnish."

THE HELIOCHROME, OR PRODUCTION OF COLOURED PHOTOGRAPHS.

We have previously remarked, that those daguerreotype portraits in which the natural tints are displayed, are coloured by the hand of the artist; and we gave a very brief account of the method of operating. It would, however, be the crowning triumph of the art, if the natural colours could be given to the image by the hand of that mysterious artist which sketches the exquisite outline. The efforts of artists and amateurs to accomplish this important desideratum have not been wanting, and some results have been obtained which seem to afford a ray of hope that the object may be ultimately attained. The chief discouragement consists in the fact, that the agency which stamps the photographic impression is evidently not the light itself, either combined into a white pencil or refracted into different hues, but some invisible medium by which the light is accompanied. The blue ray, for instance, though less luminous, will operate with infinitely greater power than the red, and the effect may even be produced when the whole of the visible spectrum is intercepted and excluded. This is a circumstance to which photographic inquirers do not seem to have sufficiently adverted, in reasoning on the probability of developing the natural colours. It would seem to preclude the possibility of doing so, except by the conceivable formation of a sensitive surface which would yield the different colours, according to the more or less powerful action of the different tints of the camera image upon it. A surface may be conceived, for instance, which, being feebly acted on, would become yellow, and if more powerfully acted on, blue. Such a surface would yield the colours correct, for the yellow pictures of the camera image are feeble photographic agents, while the blue or violet are powerful.

It must be admitted, however, that experiment has been more successful than mere theoretical reasoning would have induced us to anticipate. Twelve years ago, Sir John Herschel succeeded in procuring on photographic paper a coloured image of the solar spectrum; the colours were dark upon a light ground, and he has since succeeded in obtaining them light on a dark ground. "My own experiments," says Mr. Hunt, "have, in many instances, given me coloured pictures of the prismatic spectrum, *dark* upon a *light ground;* but the most beautiful I have yet obtained has been upon the daguerreotype iodated tablets, on which the colours have, at the same time, had a peculiar softness and brilliancy. Daguerre himself has remarked, that when he has been copying any red brick or painted building, the photograph has assumed a tint of that character. I have often observed the same thing in each variety of photographic material, *i.e.*, where a salt of silver has been used. During January of the present year (1851), I prepared some papers with the bichromate of potash, and a very weak solution of nitrate of silver: a piece of this paper was exposed behind four coloured glasses, which admitted the passage respectively of—1st, the violet, indigo, and blue rays; 2nd, the blue, the green, and a portion of the yellow rays; 3rd, the green, yellow, and orange rays; and 4th, the orange and red rays. The weather being extremely foggy, the arrangement was unattended for two days, being allowed to lie upon a table opposite a window having a southern aspect. On examining it, it had, under the respective colours, become *tinted* of a blue, a green, and a red; beneath the yellow glass the change was uncertain, from the peculiar colour of the paper; and this without a single gleam of sunshine. My numerous engagements have prevented my repeating the observations I desire on this salt, which has hitherto been considered absolutely insensible to light."

Mr. Hunt adds, that the barytic salts have nearly all of them a peculiar colorific effect; and that the muriate, in particular, gives rise to some most rich and beautiful crimsons, particularly under the influence of light which has permeated the more delicate green leaves; and also in copying the more highly coloured flowers, a variety of tintings have been observed.

The scientific world was much delighted when Mr. Hill, of New York, recently announced that he had succeeded in obtaining more than fifty pictures from nature, all as distinctly and beautifully coloured as the camera images themselves by which the effect was produced. The process was stated to be a modification of the daguerreotype, with one new material introduced; but subsequent disclosures have shown that the announcement was altogether premature, or rather a mere fabrication.

Still more recently, however, M. Niepcé de St. Victor is stated

to have succeeded in producing photograph proofs, in which the natural colours are reproduced with wonderful richness and vigour. The process is said to be at present inapplicable to portraits or views, but to be very effective where limitation as to time is not a necessary element in the experiment. He was led to the discovery of his process by tracing an analogy between the colour given to flame by certain bodies, and the colour produced upon a plate of silver when treated with chloride of sodium by a method of M. Becquerel. He found, for instance, that a chloride of strontian gave red tints very decidedly, just as that preparation thrown into burning alcohol produces coloured flames; and so for the yellow, green, and blue, with chloride of calcium, boracic acid, chloride of copper, &c. He has found that those substances which will not colour flame, or which only give white flame, yield no colour by the action of the sun's rays. M. Niepcé has hitherto failed in producing similar effects upon paper; and even on the plates employed, it was not till a very recent date that he succeeded in permanently fixing the colours. Imperfect as the process now is, it is said to produce very pleasing pictures of still life, fruits, and flowers, tinted of their natural colours.

We had written thus far when the announcement was made, that M. Niepcé had succeeded in not only greatly improving but fixing the colours. Daguerreotypes were laid before the Paris Academy of Science, upon which he had given this finishing touch to the beautiful natural images produced in the camera obscura. He now states that the production of all the colours is practicable, and he is actively engaged in endeavouring to arrive at a convenient method of preparing the plates. "I have begun," he says, "by producing in the camera obscura coloured engravings, then artificial and natural flowers, and, lastly, dead nature, a doll dressed in stuffs of different colours, and always with gold and silver lace. I have obtained all the colours; and what is still more curious and extraordinary is, that the gold and the silver are depicted with their metallic lustre, and that rock-crystal, alabaster, and porcelain are represented with the lustre which is natural to them." In producing the images of precious stone and of glass, we observe a curious peculiarity. We have placed before the lens a deep green, which has given a yellow image instead of a green one; whilst a clear green glass, placed by the side of the other, is perfectly reproduced in colour. The greatest difficulty is that of obtaining many colours at a time; it is, however, possible, and M. Niepcé has frequently obtained this result. He has observed that bright colours are produced much more vividly and much thicker than dark colours; that is to say, that the nearer the colours approach to white the more easily are they produced, and the more closely they approach to black the greater is the difficulty of reproducing them. Of all others, the most difficult to be obtained is the deep green of leaves; the light green leaves are, however, reproduced very easily. After sundry other remarks, of no peculiar moment, M. Niepcé de St. Victor informs us, that the colours are rendered very much more vivid by the action of ammonia, and at the same time this volatile alkali appears to fix the colours with much permanence. These results bring much nearer than hitherto the desideratum of producing photographs in their natural colours. The results are produced upon plates of silver which have been acted upon by chloride of copper, or some other combination of chlorine. The manipulatory details have not been published, but we understand they are very easy.

This is indeed the crowning achievement of photography. It is pleasing to ourselves, and must be equally gratifying to our readers, that we are enabled to conclude our present series of papers on this subject with such an announcement. If similar effects can be produced on paper—and this, we are fully persuaded, will soon be accomplished—nature, in all her most beautiful forms and hues—the flowers of the field, the autumnal tints of the forest—the sea, with its blue glittering waters—the rush of the cascade—the tender brilliance of the rainbow—and even the gorgeous glories of a summer sunset, exquisitely beautiful but evanescent, will soon be multiplied around us in miniature mirror-like forms of enduring beauty. Travellers will return with the lands and scenes they have visited literally mirrored in their volumes. Glimpses that can never be recalled—visions that "flit ere you can point their place"—the shifting scenes in the great panorama of nature, will thus be arrested and commemorated. The time may not be far distant when books relating to visible objects will chiefly communicate instruction in this delightful manner.

COMPENDIUM OF LOGIC.

CHAPTER II.

ANALYTICAL OUTLINE—THE SYLLOGISM—ARISTOTLE'S DICTUM.

We commenced our first or introductory chapter by defining Logic as the Science and Art of Reasoning, or, in the language of Mr. Stuart Mill,—"the science of the operations of the understanding which are subservient to the estimation of evidence," and the application of this science either to the art of reasoning in general, or to the discovery of truth in particular. We then proceeded to express our views on the value of Logic as a study, and in doing so arrived at the conclusion that, while it had been greatly overrated by some—especially by the schoolmen of the middle ages, and perhaps by the uneducated classes of the present day—it had, on the other hand, been treated with unmerited contempt by those who had studied it only in the quibbling and sophistical productions of the ante-Baconian era; and that it might be studied with decided benefit in some of the later works on the subject, not as laying down rules for reasoning, in the common acceptation of the term, but as tending to elucidate the principles on which sound reasoning depends, to guard the mind against fallacies founded on verbal ambiguities or false premisses, and finally to discipline the mental faculties in that kind of exercise which forms and moulds them to accuracy of thought and expression. We concluded our preliminary chapter with a rapid historical outline of the science, from the Greek Philosophers or Sophists who preceded the illustrious Stagyrite, to the present day.

We now proceed to give an outline of the science itself—for more than a mere compendium, or outline, would neither be consistent with our limits nor compatible with such a work as the present.

A science may be studied or explained either by analysis or synthesis, or by a combination of both. The analytical method (Gr. αναλυσις, resolving, taking asunder) is that by which any science or other subject is first viewed as a whole, or in its finished state, and then taken into fragments, and traced down to its elements. The synthetical method (Gr. συνθεσις, putting together) is that which begins at the elements or principles, and goes upward, by a process of combination, putting these elements or principles together until the complete fabric is constructed. Thus, in the instruction of children we adopt the synthetical method, beginning with the alphabet or elements, from these proceeding to syllables and words, then to clauses, sentences, and chapters, until we instruct the child to read. No other system could well be adopted in this case; and so with arithmetic, geometry, and the mathematics in general—the student must begin with the elements, and rise to the higher problems.

Still there is sometimes an advantage in adopting the analytical system, not indeed with a view to the complete exposition of any particular subject or science, but as a means of introducing it at once in a manner that will fix the attention of intelligent readers or students. Thus, there can be no higher inducement to the zealous study of astronomy than to place at once before the mind the sublime discoveries of Newton, La Place, and other astronomers, tracing back, in *general terms*, the steps by which these discoveries were attained, until we arrive at the elements, the principles, or properties of matter, from which they started. Or, to take another example, —in teaching the science of chemistry, the student's curiosity is best awakened, not by beginning with a dry detail of the simple elementary bodies, and the properties by which they are respectively distinguished, but by unfolding, in the first place, the great results of the science, by showing what it *has*

accomplished, and then proceeding from the complex to the simple—from compound bodies to proximate principles—from these to the primary elements, explaining their general relations and some of their distinguishing properties as we pass along. By this analytical method of introducing the subject, the student is prepared to commence the synthetical process, or that of studying the elements of the science, combining them, and tracing them upward in their combinations, with some idea of their bearing on the science in general, of the relative degree of attention to be given to each, and of the ultimate object to which his inquiries will lead.

The cases we have mentioned are mere illustrations. In logic we have no such discoveries as those of a Newton or a Davy to fascinate and arrest the reader's attention. Still, we proceed upon the same principle, when, in our compendium of the science, we adopt the analytical method, and begin at once with the Syllogism.

The word *syllogism* (συν, λεγω, I speak or reason together) signifies reasoning or argument put in a connected form. All argument may be reduced to the syllogism, one of the simplest examples of which is as follows:—

> All men are mortal;
> Napoleon is a man;
> *Therefore*, Napoleon is mortal.

Now, if we examine any train of reasoning, it will not be difficult to see that it may be reduced into a series of such syllogisms. In that which we have given above, it will be observed that the conclusion, "Napoleon is mortal," is deduced from the two preceding propositions, the first of which declares that "All men are mortal," and the second that "Napoleon is a man." In ordinary language or reasoning, it would be sufficient to say—"Napoleon is mortal, *for* he is a man;" in which case the conclusion is stated first, and then follows, as the *reason*, what is termed the *minor premiss*, while the *major premiss*, "All men are mortal," is left out as being superfluous in the ordinary statement of the argument, although it must be understood and admitted, to render that argument valid.

It will be found on examination, that every conclusion drawn in the course of argument rests immediately on two such conditions or premisses, one of which, the major premiss, may be termed the general principle on which the argument is based, while the other, or minor premiss, is the enunciation of the link which connects the conclusion with the principle. The second only is commonly stated,—the principle, or major premiss, being taken for granted. Thus, in Dr. Johnson's "Rasselas," Imlac, speaking of pilgrimages, says to the Prince of Abyssinia—

"Change of place is no natural cause of the increase of piety, *for* it inevitably produces dissipation of mind."

Here is an argument stated in the common form, which, in the form of an imperfect syllogism, would stand thus:—

> Change of place inevitably produces dissipation of mind;
> Therefore, Change of place is no natural cause of the increase of piety.

To the mind not sufficiently disciplined in logical or mathematical studies, this, if not a perfect syllogism, would seem to be a perfect argument. Yet, if the Prince had been a caviller, he might have replied to Imlac, and not without some appearance of reason—"What do you mean by dissipation of mind—such dissipation of mind as change of place must produce? and, whatever be the meaning of these terms, how do you prove that this state of mind is hostile to piety?" This suggests something else to be proved, or, at least, something else to be admitted, before the conclusion can be granted. The argument, therefore, in its perfect state, would take the following form:—

> *Major premiss.*—Whatever produces dissipation of mind is hostile to piety;
> *Minor premiss.*—Change of place inevitably produces dissipation of mind;
> *Conclusion.*—Therefore, Change of place is no natural cause of the increase of piety.

Even this is not a perfect syllogism, because there is a slight difference in the language of the major premiss and that which is deduced from it in the conclusion. But still, if the major and minor premisses be granted, the conclusion inevitably follows *a fortiori*; for that which is hostile or opposed to piety cannot be "a natural cause of the increase of piety."

We have said that if the premisses be granted when the argument is thus stated, the conclusion inevitably follows. This will be obvious at a glance to every mind. It follows by an absolute necessity—it has, in short, the force of demonstration, and does not admit of any dispute; whereas, in the original form of the argument, as wanting the major premiss or general principle, it might, as we have seen, have admitted of cavil, the question or dispute turning on the meaning of the words "dissipation of mind." In the syllogism, fully stated, it matters not what may be the meaning of these words. They may even have no meaning at all, and yet, if the reader admits the premisses, he cannot deny the conclusion—he is, to use a familiar expression, "shut up to it."

The major premiss is that which is generally omitted or suppressed in common reasoning, whether in conversation or in writing, because it is usually a general principle of such universal acceptance that it may be taken for granted without stating it. This is the case in the preceding instance. So, when we say, "Man is accountable, *for* he is a rational being," we omit the major premiss, which is however understood—that "rational beings are accountable." Stated, in the full syllogism form, the argument would stand thus:—

> Rational beings are accountable;
> Man is a rational being;
> Therefore, man is accountable.

But it is not always the major premiss that is suppressed in the common forms of speech. It is, indeed, generally the most obvious—generally a principle which no one would think of denying; but this is not always the case. For instance, there are probably thousands who would demur at a conclusion drawn in the following abrupt manner:—

> The ox is a horned animal;
> Therefore, the ox ruminates (or chews the cud).

Whereas, if we stated the argument thus, it would be universally admitted:—

> All horned animals ruminate;
> Therefore, the ox ruminates.

Now it will be seen that neither of these is a syllogism, properly speaking—the former is deficient in the major, the latter in the minor premiss: the argument is therefore incomplete in both; and yet, in common conversation or writing, the second is the form which it would naturally assume, or still more simply as follows—"The ox ruminates, for all horned animals do so." But, if we develop it fully, it forms this syllogism:—

> *Major Premiss.*—All horned animals ruminate;
> *Minor Premiss.*—The ox is a horned animal;
> *Conclusion.*—Therefore, the ox ruminates.

Or, if we choose, the minor premiss may be placed first:—"The ox is a horned animal; but all horned animals ruminate; therefore, the ox ruminates." Or even the conclusion may come first; and then the premisses become the *reasons*, and instead of the conjunction *therefore*, we use *for* or *because*—"The ox ruminates, *for* the ox is a horned animal, and all horned animals ruminate;" or—"The ox ruminates, because all horned animals ruminate, and the ox is a horned animal."

In this argument, it will have been observed that the major premiss is that which is *least* obvious, namely, that "all horned animals ruminate"—a fact of which many people are ignorant, while all are aware of the truth of the minor premiss, namely, that "the ox is a horned animal." Hence it happens that, in this case, contrary to the general rule, the minor premiss would be suppressed, and the major premiss alone introduced, in speaking or writing according to common usage.

When one of the premisses is thus suppressed, whether the major or the minor, the syllogism is termed an *enthymeme*. And here it may be proper to state that this suppression of one of the premisses constitutes a frequent source of fallacy, either designed or unintentional. Sophists or casuists have often recourse to the enthymeme when they are aware that the com-

plete syllogism, or—to speak in other words—the argument fully developed, would prove its own confutation. The false or doubtful premiss is suppressed or taken for granted, while that which is unquestionably true is urged with emphatic prominence, and thus a fallacious conclusion is arrived at—a conclusion, the fallacy of which would be unmasked if the other understood premiss were expressed. Logic does something, at least, when it puts the reasoner on his guard against a conclusion, or inference, deduced from only one premiss. It teaches him to look universally for two premisses, one of which alone may be expressed; but in that case the other must be obvious, otherwise the argument is doubtful.

We have considered the syllogism only as the logical development of one argument. A chain of reasoning consists of a series of arguments, which may be always divided or developed into so many regular syllogisms, each having for its *minor premiss* the *conclusion* of that which precedes it. Thus—"The English are a brave people; a brave people are free; a free people are happy; therefore, the English are happy"—constitutes a chain of reasoning, which may be developed as follows:—

The English are a brave people;
A brave people are free;
Therefore, *the English are free:*

A free people are happy;
The English are free;
Therefore, the English are happy.

However long the continuous chain of reasoning, it may be uniformly divided in this manner. It is, however, equally conclusive when stated in the short undeveloped manner, and then it is termed a *sorites*—a word meaning a *heap*. The sorites is the usual form in which a string of arguments is stated, although, as we have shown above, the sorites may always be reduced to a series of regular syllogisms. In other words, every chain of reasoning may be so developed and tested.

Hence we conclude, that the syllogism runs through all valid reasoning. Every argument or chain of arguments may be reduced to a syllogism, or to a series of syllogisms. All reasoning is, therefore, essentially the same. We sometimes hear of mathematical reasoning, logical reasoning, metaphysical reasoning, as if it were possible to reason on different principles according to the nature of the subject under discussion. The truth is, that all sound reasoning, whether metaphysical or mathematical, is strictly logical reasoning. Euclid's Elements may be reduced to a series of syllogisms. So may all the argumentative portions of the writings of Dr. Adam Smith, of Jeremy Bentham, of Dugald Stewart, of Hume, Reid, or Montesquieu. The actual reasoning process is the same in all cases, however various the subject. Every conclusion correctly deduced, whether in physics, metaphysics, political economy, or mathematics, must rest upon two premisses, both of which must be true, or must be admitted as such, otherwise the inference drawn is unwarranted.

Here we must remind the reader, however, that while it is the province of logic to determine whether the conclusion really follows from the premisses, logic has nothing to do with the truth of the premisses themselves. An argument leading to a gross absurdity, may be a perfectly logical argument. The following apposite example of this is given by Archbishop Whately:—

All the ape-tribe are originally descended from reptiles or insects;
Mankind are of the ape-tribe;
Therefore, mankind are originally descended from reptiles or insects.

This is exactly the reasoning pursued by the ingenious author of the "Vestiges of the Natural History of Creation," who, of course, takes it for granted, or thinks he has sufficiently proved, that the premisses in this case are true, and hence the truth of the conclusion. Admitting the premisses, no one can deny the conclusion—the argument is strictly logical. Yet it is only the admirers of the "gradual development theory," who will see anything but nonsense either in the major premiss, the minor premiss, or the conclusion of the above syllogism. An argument may therefore be logically sound, and yet the conclusion or inference be not only false but absurd. Indeed, if the premisses be untrue, then the more logical and sound the reasoning, the more inevitably false will be the conclusion.

On the other hand, a just and correct conclusion may be inferred by a strictly logical argument from premisses, of which at least *one* is false. Thus—

All bodies moving round the sun are planets;
Neptune moves round the sun;
Therefore, Neptune is a planet:

Here the conclusion is perfectly correct; so is also the minor premiss. The argument is perfectly logical—it leads to a just conclusion, and yet it starts from a false major premiss—namely, that "all bodies moving round the sun are planets;" for everybody knows that a host of comets, far exceeding the planets in number, and totally different in their orbits and character, likewise move round the sun. Hence may be deduced the important rule, that when we admit or perceive a conclusion or inference to be true, we must not be rash in deciding that, *therefore*, both the premisses are true.

There are different forms or figures of the syllogism, all of which, however, may be reduced to the type of that simple construction which appears in the preceding examples. There are logical rules for the conversion of all other forms of the syllogism into such as these. At present we shall only give a few examples of different figures:—

No delinquency deserves free pardon;
All forgery is delinquency;
Therefore, no forgery deserves free pardon.

All the truly noble are virtuous:
Some who are called noble are not virtuous;
Some who are called noble are not truly so.

No branch of science can be made absolutely perfect:
All branches of science are worthy of diligent culture;
Some things worthy of diligent culture cannot be made absolutely perfect.

Some taxes on the necessaries of life are oppressive:
All that is oppressive ought to be repealed;
Some taxes on the necessaries of life ought to be repealed.

These examples are given merely to show the variety of form of which the syllogism admits. The logical distinctions, by which they are classed under different figures, will be stated in a future chapter. In the meantime we proceed to remark that, however different in form, every argument, and therefore every syllogism, may be reduced to the simple type which we selected as our first example, namely,—

All men are mortal:
Napoleon is a man;
Therefore, Napoleon is mortal.

The logical validity of this syllogism does not, as we have already stated, depend on the truth of the premisses. Thus, we may substitute terms which have no meaning whatever, and yet the conclusion will be undeniable. For example:—

(1) All A is B:
(2) Some C is A;
Therefore, (3) some C is B.

Here we may attach to A, B, and C whatever meanings we choose: let these meanings be what they may, if propositions 1 and 2 be admitted, proposition 3 must be admitted also. A, here, stands for a class, of which certain qualities or properties or characteristics (B) are asserted, as belonging to every individual in that class (1). But another thing (C) is said to be included in class A (2). Hence it follows, that the properties or qualities (B) predicated of the whole class (A) may be, in like manner, predicated of any individual (C) included under that class (3).

Hence Aristotle's general statement of the syllogism, namely:—

"*That whatever is predicated (i. e. affirmed or denied) universally, of any class of things, may be predicated in like manner (i. e. affirmed or denied) of anything comprehended in that class.*"

This is the syllogism stated in general terms, and so as to unfold the principle on which it rests—a principle commonly called the *dictum de omni et nullo*, or the "statement concerning all and none," and termed by logicians "Aristotle's Dictum," from the name of its first propounder. The *dictum de omni* is that in which something is *affirmed* of a whole class; thus, "All good men are beloved; Socrates is a good man; therefore, Socrates is beloved"—constitutes a syllogism falling under this description. Again—"No tyrant deserves to prosper: the Emperor of Russia is a tyrant; therefore, he does not deserve to prosper," is a specimen of the *dictum de nullo*, in which it will be seen that "deserving to prosper" is *denied* of the whole class of tyrants, and therefore is denied of the Emperor of Russia, as one individual of that class.

But how do we know that the Emperor of Russia may not have redeeming qualities which would entitle him to "deserve to prosper," although he does really belong to the class of tyrants? It is stated (as a general rule itself), that all général rules have their exceptions; and who knows that the Emperor of Russia may not be the very exception in this case, if such an exception exists? It is not the province of logic to investigate the truth of the premisses on which a conclusion is founded, and therefore, when we say, in the major premiss, that "no tyrant deserves to prosper," and again, in the minor premiss, that "the Emperor of Russia is a tyrant," the rules of logic, or, in other words, of sound reasoning—assuming the *truth* of both premisses—shut us up to the conclusion that "he does not deserve to prosper." It will thus be perceived that an argument, stated in this syllogistic manner, does not provide for exceptions; and hence, an important objection which has been urged against the syllogism as *a mode of reasoning*—an objection so important, indeed, and meeting us at the very threshold, that we must consider it calmly and impartially before we proceed a step further.

The objection, briefly stated, is this:—Taking, for example, the simplest form of the syllogism—"All men are mortal: Napoleon is a man; therefore, Napoleon is mortal,"—Dr. Campbell, and other objectors, assert that the conclusion is involved in the major premiss, for, unless Napoleon is mortal, all men are not mortal. We must therefore be assured, in the first place, that Napoleon is subject to mortality, before we can affirm, as a rule admitting of no exceptions, that all men are mortal. If there be one exception to the rule, Napoleon may be that very exception. If there be no exceptions, this can only be fully proved by waiting till Napoleon dies, and then the fact that he is mortal will be obvious without the help of a syllogism. "Therefore," say the anti-syllogistic objectors, "you first prove that all men are mortal, by proving Napoleon to be mortal, and then again, reversing the process, from the statement that all men are mortal, you infer Napoleon to be mortal."

This argument, first stated in its full force by the celebrated Dr. Campbell, and seeming, as it does, to strike at the very root of the syllogism—nay, of the whole science of logic—cannot be passed over lightly. Let us, therefore, hear it expressed in the words of one of the objectors themselves—a logician of the school of Dr. Campbell:—"Now," says Bosanquet, "it is evident that proof may reasonably be required of the premisses of a syllogism, and that the engine of reasoning ought to be capable of supplying it; otherwise, it must be imperfect. And this instrument must be applicable to the truth of particulars, since these are the parts which make up the proposition. But since all the individual cases must be established to warrant a general unexceptionable rule, why should not this instrument, when *certain* conclusions are sought after, supersede the proof by general axioms, since the conclusion itself must have been proved among the rest? For surely it is easier to prove for *certain* one particular instance, than the whole multitude of cases without exception. And if there is one exception only, this may be the very conclusion and question itself. It is far easier to prove that Socrates, Plato, or Xenophon has died, than that all men have died. It were far easier to prove for *certain*, that a particular miracle is an imposture, than that all miracles are impostures."

Such is the argument, as stated by Bosanquet, and then he proceeds to give a few illustrations of what would be termed, by this school, the fallacy of syllogistic reasoning. Some of these we shall give, to place before the reader the objection in all its force; but let us, in the first place, advert to the fact that our author, in the preceding extract, speaks of the syllogism as "the engine of reasoning," whereas we have hitherto represented it as merely *reasoning developed*—not as an engine of reasoning at all—not even a particular kind of reasoning; but simply as the full and formal development of all reasoning whatever. This is an important observation in passing, which the reader is requested to keep in mind. And now we give the argument the benefit of Mr. Bosanquet's illustrations. He says:—

"'All men must necessarily be born of woman,' is an universal proposition; from which we syllogistically derive the conclusion, that Socrates was so born. And this is a true conclusion.

"All men are born of woman: Alexander was a man; Alexander, therefore, was born of woman. This is true also.

"All men are born of woman: Adam was a man; therefore, Adam was born of a woman.

"The above proofs, estimated logically and syllogistically, rest exactly upon the same evidence.

"All birds are hatched from eggs: the first bird, therefore, if there ever was one. But all eggs are produced by birds; the egg, therefore, that produced the first bird, by a bird prior to the first."

To these illustrations, Bosanquet adds the following remark, which is likewise worthy of attention, as showing the absurd and fallacious uses to which even the founder of logic himself attempted to apply the syllogism:—"The value of any system," he adds, "is most fairly estimated by the use and application made of it by its inventor. The above are the arguments used by Aristotle himself, to prove that the human race existed from eternity, and that the world never had a beginning."

Now, it must be frankly allowed, that when the syllogism is applied in this manner, or expected to work out unknown truths which cannot be discovered or made manifest by means of ordinary reasoning, its character, powers, and uses are totally misunderstood. The syllogism cannot go a step further than common reasoning, because it is merely a formal expansion or development of such reasoning. The only virtue of the syllogism is, that it dissects and lays bare every sinew and nerve of the argument, so that, if a fallacy lurk therein, it may be detected at once. As has been repeatedly stated, it is not a particular kind of reasoning, but simply the common process of reasoning unfolded in all its parts and proportions. In this respect it may be compared to Euclid's Elements, in which things seemingly self-evident are stated with as much care and precision, as if they were new and profound truths; the object of the syllogism being to gather up every link in the argument or chain of reasoning, so that, when a doubt occurs, the weak or unconnected part—in other words, the source of the fallacy—may be at once exposed to view.

Such being really the nature of the syllogism, let us take another illustration of a syllogistic *absurdity* from the same writer:—"The following," he says, "is certainly a valid argument, if there is any virtue in form; and if induction is truly said to be a kind of syllogism, a better illustration cannot be given of the foregoing reasoning.—A gentleman, coming home at the usual hour, ordered up dinner. 'Sir,' said the servant, 'there is no dinner ready. You must know that you are ruined.' 'Go, I say, immediately,' replied the master, 'and fetch it up. My dinner has been ready at this very hour for the last twenty years: therefore, it must be ready now.'"

This illustration is intended to ridicule the syllogism; yet it is by no means so strong as the preceding case, in which, from the enunciated fact that "all men are born of woman," the logician is supposed to infer that "Adam was born of woman." But taking even this strongest case, we hold that if the premisses be true, and even whether they be true or not, the argument is perfectly valid. There is really no flaw in the reasoning. The conclusion, though correctly argued, is false; but this arises from the fact, that one of the premisses is false, namely, the major premiss, that "all men are born of

woman." The first man could not be so born, and therefore, in laying down the general rule, this exception must be understood, or the rule can only be admitted with this limitation.

The syllogism may be defined, a mathematical sequence. When it is correctly stated, the conclusion inevitably follows, whether one or both of the premisses be true or false. These must be thoroughly tested in the first place—but this is not a logical process—and then it is the office of the judgment to estimate how far they warrant the conclusion.

"Some persons," says Archbishop Whately, "have remarked of Aristotle's 'Dictum,' (meaning it as a disparagement,) that it is merely a somewhat circuitous *explanation of what is meant by a class.* It is, in truth, just such an explanation of this as is needful to the student, and which must be kept before his mind in reasoning. For we should recollect, that not only every class [the sign of which is a "common term"] comprehends under it an indefinite number of individuals—and often of other classes—differing in many respects from each other, but also most of those individuals and classes may be referred, each, to an indefinite number of classes, according as we *choose to abstract* this point or that from each. Now, to *remind* one, on each occasion, that so and so is referable to such and such a class, and that the class which happens to be before us comprehends such and such things—this is *precisely all that is ever accomplished by reasoning.*"

Accepting this as a just definition of reasoning, and again regarding the syllogism as merely "reasoning developed to its full extent," we find that the objections of Dr. Campbell and his followers, either do not apply to the syllogism, or must be equally applicable to all reasoning.

On this very interesting and somewhat difficult subject, Mr. Stuart Mill differs from Archbishop Whately, although, at the same time, he admits that the syllogism *does* embrace something more than a mere *petitio principii* (or, begging of the question). "Archbishop Whately," he says, "has contended that syllogizing, or reasoning from generals to particulars, is not, agreeably to the vulgar idea, a peculiar *mode* of reasoning, but the philosophical analysis of the mode in which all men reason, and must do so if they reason at all. With the deference due to so high an authority, I cannot help thinking that the vulgar notion is in this case the more correct. If, from our experience of John, Thomas, &c., who once were living, but are now dead, we are entitled to conclude that all human beings are mortal, we might surely, without any logical inconsequence, have concluded at once from those instances, that the Duke of Wellington is mortal. . . . Not only *may* we reason from particulars to particulars, without passing through generals, but we perpetually do so reason. All our earliest inferences are of this nature. From the first dawn of intelligence we draw inferences, but years elapse before we learn the use of general language. The child, who, having burnt his fingers, avoids to thrust them again into the fire, has reasoned or inferred, though he has never thought of the general maxim, fire burns. . . . In the same way, also, brutes reason. Not only the burnt child, but the burnt dog, dreads the fire. . . . All inference is from particulars to particulars. General propositions are merely registers of such inferences already made, and short formulæ for making more. The major premiss of a syllogism, consequently, is a formula of this description: and the conclusion is not an inference drawn *from* the formula, but an inference drawn *according to* the formula: the real logical antecedent, or premisses, being the particular facts from which the general proposition was collected by induction. . . . The value of the syllogistic form, and of the rules for using it correctly, does not consist in their being the form and the rules according to which our reasonings are necessarily, or even usually, made; but in their furnishing us with a mode in which those reasonings may always be represented, and which is admirably calculated, if they are inconclusive, to bring their inconclusiveness to light. . . . . These are the uses of the syllogism, as a mode of verifying any given argument. Its ulterior uses, as respects the general course of our intellectual operations, hardly require illustration, being in fact the acknowledged uses of general language. They amount substantially to this, that the inductions may be made once for all: a single careful interrogation of experience may suffice, and the result may be registered in the form of a general proposition, which is committed to memory or to writing, and from which afterwards we have only to syllogize."

These somewhat extended extracts are given as affording the best explanation we have seen, of the actual value and meaning of the syllogism. This may be deemed the fundamental question on which the utility of logic depends, for if the syllogism proves nothing—if it be a mere *petitio principii*, the study of logic must be useless, and the science rests on a fallacy. This preliminary question demands, therefore, full consideration, and we think the preceding observations may enable the reader to advance to the synthetical study of the science with a just and intelligent appreciation of what it professes to accomplish. Lay down the premisses correctly, and the syllogism cannot mislead. It is for observation, experience, or judgment, to decide as to the truth of the premisses—the syllogism only draws the conclusion, and does so with infallible accuracy.

Few general truths, apart from mathematical axioms or theorems, admit of being stated as rules or facts that do not admit of any exceptions. When we say that all equilateral (or equal-sided) triangles have their three angles equal, and that any given triangle, A B C, is equilateral, we draw the syllogistic inference without possibility of error, that all the angles of the triangle, A B C, are equal; because, in this case, the major premiss is founded on positive knowledge of the fact, and may therefore be stated as a rule that does not admit of doubt or exception. But when—putting revelation aside—we say that "all men are mortal," we only mean that we have found it to be so, as far as our experience or knowledge extends; and hence a strong probability, amounting to a moral certainty, that John, Thomas, Alexander, or any other man, is mortal. The conclusion goes only as far as the premisses. State the premisses with positive certainty, and then, by the strict rules of logic, the conclusion may be stated with positive certainty also; but where there is the slightest doubt upon the premisses, the same doubt will rest on the conclusion. If any distinction exists between mathematical reasoning, and any other kind of reasoning, it is, that in the case of mathematical reasoning the premisses cannot be doubted or questioned, and do not admit of exceptions. Give us on any other subject equal assurance of the truth of the premisses, and then we can draw the conclusion with equal certainty—the *reasoning* or *inferring* process is exactly the same in both cases.

Having thus explained the nature and province of the syllogism, let us take the following examples from Whately, to show how an argument merely *apparent*, or, in other words, inconclusive or fallacious, may be presented in a form which would readily impose on many readers:—

Every rational agent is accountable:
Brutes are not rational agents;
Therefore, Brutes are not accountable.

Or, again:—

All wise legislators suit their laws to the genius of their nation:
Solon suited his laws to the genius of his nation;
Therefore, Solon was a wise legislator.

These are arguments, or rather *apparent* arguments, which would, in all probability, impose upon a common audience. Yet, as the above-named author remarks, they exactly correspond with the following, of which the absurdity is manifest:—

Every horse is an animal:
Sheep are not horses;
Therefore, Sheep are not animals.

Or:—

All vegetables grow:
Animals grow;
Therefore, Animals are vegetables.

Now, it is one of the offices of logic to investigate the principle or source of the fallacy in these and similar cases, and to lay down rules for detecting it. Some of these we shall explain in one or two subsequent chapters.

DESCRIPTION OF THE MAN-LIFTING ENGINE ERECTED AT UNITED MINES, GWENNAP.

BY CAPTAIN W. FRANCIS.

The principle adopted in the construction of this machinery, is the same as that on which the machine at Tresavean mine had previously been constructed, and which may shortly be stated to consist of wood rods, having a reciprocating motion, with platforms attached to them, on which the men stand, simply, and step from the platform on one rod to that on the other, at every turn of the stroke which the rods make, and the arrangements in both are very similar. The only differences of any importance, consist in the engine at the United Mines being placed at a distance of about forty fathoms from the shaft, instead of being near to it, as at Tresavean; and the rods at the former place being balanced underground by what are termed balance levers, instead of balance bobs; a further description of which will be given hereafter.

The engine employed is a 32-inch cylinder, double acting, 6 feet stroke, equal beam. Besides giving motion to the machinery for lowering and raising the miners, it crushes nearly the whole of the ores which the mines produce; and it also works two lifts of pumps, which are required in sinking the shaft below the 170th fathom level. These various purposes to which it is applied, require that it should be always at work, instead of being worked only at stated periods of the day, as is the case with the engine at Tresavean mine.

The wheels on the crank-shaft are each 2 feet 4 ins. diameter; and they drive two others of 14 feet diameter, each; consequently, six strokes of the engine are required to make one revolution of the large wheels. To one of the arms of each of the large wheels, the horizontal rods are attached at a distance of 6 feet from the centre, thus making the length of the stroke 12 feet.

The shaft to which the machinery is applied, is a large one; being 12 feet long, by 8 feet wide at one end, and 7 at the other.

The narrow end of the shaft, for 4 feet in length, is divided from the other part by boarding, and is used for drawing stuff through. Of the remaining space, a part 8 feet in length by 2 feet 6 inches in width, is appropriated to the rods and platforms of the Man-Machinery, and a ladder road, which has been provided for the men to resort to, in the event of an accident to the machinery. The space occupied by the rods and platforms alone, is 4 feet 6 inches long, by 2 feet 6 inches wide, which is found to afford sufficient room for them. That part of the shaft which remains unappropriated for the present, is 8 feet in length, by about 5 feet in width, and is reserved for pump work, should it be necessary hereafter to erect an engine on this shaft for drawing water.

The wood rods, used for lowering and raising the men, are $7\frac{1}{2}$ inches square for the first 60 fathoms below the surface, 7 inches square for the next 100 fathoms, and $6\frac{1}{2}$ inches square for the remaining 50 fathoms, making together 210 fathoms—the depth to which the machinery is now applied; but this will be increased as the shaft is made deeper, which is now being done.

The distance from centre to centre of the rods is 2 feet; and the size of the platforms, on which the men stand, is 18 inches long by 15 inches wide; the latter are so fixed on the rods as to have a space of 6 inches between them, at the time the men step from one to the other.

The length of the stroke being 12 feet, the platforms are, consequently, fixed at that distance from each other, on each rod.

The weight of the rod is balanced, partly by counter weight on the back end of each of the bobs, at the surface, and partly by means of three balanced levers underground; one of which is at the adit level, one at the forty-five fathom level, and the third at the one hundred and twelve fathom level. The manner of applying these levers is as follows:—A pinion wheel suspended by side links from the end of the lever, works in the racks, and revolves as the rods make their stroke without varying its position up or down more than a few inches. The lever is suspended from timber placed in the shaft for that purpose: at the back end of it there is a box hung, which holds a ton of ballast; and as the length from the point of suspension to the box, is four times greater than that to the end of the lever from which the wheel is suspended, it follows that a portion of the weight of the rods, equal to four tons, is thus counter-balanced.

The great object gained by the use of levers, instead of balance bobs, is a considerable saving of expense, as the ground which is required to be excavated for them, and the materials of which they are made, are both very much less than would be necessary for bobs. At the same time it must be admitted that a greater amount of friction is caused by the levers than by balance bobs, arising from the wheels of the former having a tendency to throw the rods asunder, and thereby causing them to press against the stays by which they are kept in their position.

The loss of power thus sustained has not been very nicely ascertained, but it is believed not to be very considerable; care, however, in the application of these balance levers is requisite to prevent friction, which otherwise may be so much as to overcome the benefit to be derived from the economy of their construction.

The relief afforded to the miners by this machinery can scarcely be estimated, and can only be fully appreciated by those, who, after having nearly their whole strength and spirits exhausted by working eight hours, and even longer in some instances, in an atmosphere varying in temperature from 95° to 105° Fahrenheit, had formerly to climb to the surface by ladders. The amount of physical suffering which it alleviates is almost incalculable; and this benefit would, of itself, be full compensation for the outlay incurred in its erection; but the advantages, in a pecuniary point of view, which it affords, are equally striking, and will be very apparent by the following statement:—

The number of men now being lowered and raised by this machinery, is about 450; and of boys, 50; making together 500 persons. The average depth to which they are sent is 200 fathoms, which requires between sixteen and seventeen minutes, and, of course, the same time is required to bring them up, making together thirty-four minutes for the descent and ascent, whilst by ladders it would be full sixty-five minutes; thus showing a saving in time of a half-hour per day, or in round numbers, of 150 hours in the year; which should be valued at fourpence per hour, and which would amount, on

Four hundred and fifty men, to	£1125	0	0
Fifty boys at twopence per hour for the same number of hours, will amount to	62	10	0
	£1187	10	0

It has been already stated, that the engine is applied to other purposes than that of working the man-machinery. A careful dissection of the expense of working it has been made, by which it is shown that the charges on account of working the machinery in question, do not exceed £30 per month, or (per annum)	£1187	10	0
	360	0	0
	£827	10	0

Thus it appears that a saving of upwards of £800 per annum is effected, without including in the estimate anything more than the mere difference in time, which is gained by the machinery. It is difficult to calculate correctly the increased amount of labour derived from these 500 persons on other grounds; but it may be easily conceived, that, as the labour of coming to the surface is now almost superseded, much of the strength which was before required to bring them up by ladders, is now expended in their work.

The cost of the machinery, and the erection of it, exclusive of the engine, which had been provided before, was somewhat less than £2000; it will, therefore, be repaid within two and a half years. The cost of erecting an engine of sufficient power for working the machinery would be about £1000; but in all cases where the engine can be applied to other purposes, it may be done with advantage, by making it powerful enough to accomplish the additional work which it would be required to perform.

PRINCIPLES OF ALGEBRA.

CHAPTER XIII.

THE BINOMIAL THEOREM.

The Binomial Theorem is an algebraic formula for expressing any power or root of a binomial expression in a series consisting of single terms.

Let m be any positive number whole or fractional, and let it be required to exhibit the expansion of $(a + x)^m$.

To determine the literal parts of the expansion.

1° Since $a + x = a\,(1 + \frac{x}{a})$, $\therefore (a + x)^m = a^m\,(1 + \frac{x}{a})^m$ and since every power or root of 1 is 1, consequently the first term

of the expansion of $(1 + \frac{x}{a})^m$ is 1, and therefore the first term in the expansion of $a^m(1 + \frac{x}{a})^m$ or its equal $(a + x)^m$ must be a^m.

2° Since $(a + x)^m \times (a + x) = (a + x)^{m+1}$, which is equal to each term in the expansion of $(a + x)^m$ multiplied by $(a + x)$, $\therefore a^m \times (a + x) = a^{m+1} + a^m x =$ the first term and the literal part of the second in the expansion of $(a + x)^{m+1}$. But the complete second term may have a coefficient B which will $= 1$ should there be no coefficient.

3° Since $(a + x)^{m+1} \times (a + x) = (a + x)^{m+2}$ which is $=$ to each term in the expansion of $(a + x)^{m+1}$ multiplied by $(a + x)$; $\therefore (a^{m+1} + \mathrm{B}a^m x) \times (a + x) =$ $a^{m+2} + (\mathrm{B} + 1)a^{m+1}x + a^m x^2 =$ the two first terms in the expansion of $(a + x)^{m+2}$ and the literal part of the third.

4° Increasing the exponent again by 1, then, in like manner, the expansion of $(a + x)^{m+3}$ will be $=$ each term in the preceding expansion multiplied by $(a + x)$;
$\therefore (a^{m+2}) + (\mathrm{B} + 1)a^{m+1}x + a^m x^2) \times (a + x)$, omitting coefficients, $= a^{m+3} + a^{m+2}x + a^{m+1}x^2 + a^m x^3 =$ the literal parts of the four first terms of the expansion of $(+ x)^{m+3}$. And

5° Generally, if the exponent m be increased continually by 1 to n, we shall have for the literal parts of $n + 1$ terms in the expansion of $(a + x)^{m+n} = a^{m+n} + a^{m+n-1}x + a^{m+n-2}x^2 + a^{m+n-3}x^3 +$ &c. $=$ a geometrical series of which a^{m+n} is the first term and $\frac{x}{a}$ the common ratio.

To determine the coefficients of these terms.

1° Since it appears that, if the coefficient of the second term in the expansion of $(a + x)^{m+1}$ be B, the coefficient of the succeeding expansion will be $\mathrm{B} + 1$, and that every addition to the exponent is an equivalent addition to the coefficient of the second term, it follows that the difference between the coefficient of the second term and the exponent must be the same in every expansion, whatever be the value of m; but if $m = 0$, then $(a + x)^{m+1} = (a + x)^1 = a + 1x$, and the difference between the exponent and the coefficient of the second term is 0; therefore the difference must always be 0; that is, *the coefficient of the second term in any expansion must always be equal to the exponent.*

2° Putting $m + n = r$, then $(a + x)^{m+n} = (a + x)^r$. Now let $(a + x)^r = a^r + \mathrm{B}a^{r-1}x + \mathrm{C}a^{r-2}x^2 + \mathrm{D}a^{r-3}x^3 +$ &c. ... (a) where $\mathrm{B} = r$, and C, D, &c. are undetermined. Square each side of this equation and there results for the square of the first side $(a^2 + 2ax + x^2)^r$ which may be put under the form $[(a^2 + (2ax + x^2)]^r$. The quantity within the brackets being a binomial, the first term of which is a^2 and the second $(2ax + x^2)$, it is obvious that to exhibit the required expansion of this member, it will be necessary only to write a^2 for a and $(2ax + x^2)$ for x in the expansion of $(a + x)^r$ in equation (a), for by substitution $[a^2 + (2ax + x^2)]^r = a^{2(r)} + \mathrm{B}a^{2(r-1)}(2ax + x^2) + \mathrm{C}a^{2(r-2)}(2ax + x^2)^2 + \mathrm{D}a^{2(r-3)}(2ax + x^2)^3 +$ &c.; and by actual involution of the quantities within the parentheses, there results for the terms of the second member,

$$\left.\begin{array}{l} a^{2r} + 2\mathrm{B}a^{2r-1}x + \mathrm{B}a^{2r-2}x^2 + 4\mathrm{C}a^{2r-3}x^3 + \&c. \\ \quad + 4\mathrm{C}^2a^{2r-2}x^2 + 8\mathrm{D}a^{2r-3}x^3 + \&c. \end{array}\right\} \ldots (\mathrm{A})$$

Also for the square of the second member of eq. (a), the result is

$$\left.\begin{array}{l} a^{2r} + 2\mathrm{B}a^{2r-1}x + 2\mathrm{C}a^{2r-2}x^2 + 2\mathrm{D}a^{2r-3}x^3 + \&c. \\ \quad + \mathrm{B}^2a^{2r-2}x^2 + 2\mathrm{BC}a^{2r-3}x^3 + \&c. \end{array}\right\} \ldots (\mathrm{B})$$

Now since these series (A) and (B) are identical whatever be the value of x, compare the homologous terms.

$$2\mathrm{B} = 2\mathrm{B} \quad . \quad . \quad . \quad \therefore \quad \mathrm{B} = \mathrm{B} = r$$

$$\mathrm{B} + 4\mathrm{C} = 2\mathrm{C} + \mathrm{B}^2 \quad . \quad \therefore \quad \mathrm{C}\frac{\mathrm{B}(\mathrm{B} - 1)}{2} = \frac{r(r-1)}{2}$$

$$4\mathrm{C} + 8\mathrm{D} = 2\mathrm{D} + 2\mathrm{BC} \quad \therefore \mathrm{D} = \frac{\mathrm{C}(\mathrm{B} - 2)}{3} = \frac{r(r-1)(r-2)}{2 \cdot 3}$$

By proceeding in the same manner we would find for the next coefficient in eq. (a).

$$\mathrm{E} = \frac{\mathrm{D}(\mathrm{B} - 3)}{4} = \frac{r(r-1)(r-2)(r-3)}{2\,.\,3\,.\,4}$$

and so for any farther coefficients, F, G, &c.

3° Now $\mathrm{B} = r$ by 1°; hence the expansion of $(a + x)^r$ equation (a),

$$(a + x)^r = a^r + ra^{r-1}x + \frac{r(r-1)}{2}a^{r-2}x^2 + \frac{r(r-1)(r-2)}{2\,.\,3}a^{r-3}x^3 + \&c.$$

and restoring the value of $r = m + n$, and putting $m = 0$, we have

$$\text{I. } (a + x)^n = a^n + na^{n+1}x + \frac{n(n-1)}{2}a^{n+2}x^2 + \frac{n(n-1)(n-2)}{2 \cdot 3}a^{n-3}x^3 + \&c.$$

Putting $a = m + n$, and $m = -(s + n)$, we have

$$\text{II. } (a + x)^{-s} = a^{-s} - sa^{-(s+1)}x + \frac{s(s+1)}{2}a^{-(s+2)}x^2 - \frac{s(s+1)(s+2)}{2 \cdot 3}a^{-(s+3)}x^3 + \&c.$$

Putting $r = m + n$ and $m = \frac{p}{q}$, we have

$$\text{III. } (a + x)^{\frac{p}{q}} = a^{\frac{p}{q}} + \frac{p}{q}a^{\frac{p}{q}-1}x + \frac{\frac{p}{q}(\frac{p}{q}-1)}{2}a^{\frac{p}{q}-2}x^2 + \frac{\frac{p}{q}(\frac{p}{q}-1)(\frac{p}{q}-2)}{2 \cdot 3}a^{\frac{p}{q}-3}x_3 + \&c.$$

Putting $r = m + n$ and $m = -(\frac{p}{q} + n)$, we have

$$\text{IV. } (a + x)^{-\frac{p}{q}} = a^{-\frac{p}{q}} - \frac{p}{q}a^{-(\frac{p}{q}+1)}x + \frac{\frac{p}{q}(\frac{p}{2}+1)}{2}a^{-(\frac{p}{q}+\ )}x^2 - \frac{\frac{p}{q}(\frac{p}{q}+1)(\frac{p}{q}+2)}{2 \cdot 3}a^{-(\frac{p}{\ }+3)}x^3 + \&c.$$

Note.—The first of these series exhibits the expansion when the exponent of the binomial is a *positive integer*; the second, when the exponent is a *negative integer*; the third, when the exponent is a *positive fraction*; and the fourth when the exponent is a *negative fraction*. The first is the general expression of the rules laid down for the involution of binomial quantities, and consists of $n + 1$ terms. In the other cases the series never terminates and the development constitutes an *infinite series.*

Application of the Binomial Theorem.

To expand $(a + x)^n$ when n is a positive, or negative integer.

Example 1. Let $n = 5$, then $n - 1 = 4$, $n - 2 = 3$, &c.

a^n	is a^5 . .	$= a^5$
$na^{n-1}x$	$5a^4x$.	$= 5a^4x$
$\frac{n(n-1)}{2}a^{n-2}x^2$ . . .	$\frac{5 \cdot 4}{2}a^3x^2$	$= 10a^3x^2$
$\frac{n(n-1)(n-2)}{2 \cdot 3}a^{n-3}x^3$.	$\frac{5 \cdot 4 \cdot 3}{2 \cdot 3}a^2x^2$	$= 10a^2x^3$
$\frac{n(n-1)(n-2)(n-3)}{2 \cdot 3 \cdot 4}a^{n-4}x^4$.	$\frac{5 \cdot 4 \cdot 3 \cdot 2}{2 \cdot 3 \cdot 4}ax^4$	$= 5ax^4$
$\frac{n(n-1)(n-2)(n-3)(n-4)}{2 \cdot 3 \cdot 4 \cdot 5}a^{n-5}x^5$	$\frac{5 \cdot 4 \cdot 3 \cdot 2 \cdot 1}{2 \cdot 3 \cdot 4 \cdot 5}a^0x^5$	$= x^5$

$\therefore (a + x)^5 = a^5 + 5a^4x + 10a^3x^2 + 10a^2x^3 + 5ax^4 + x^5$

But should $+ x$ become $- x$ then all its *odd* powers, or all the *even* terms of the expansion, would become negative. Thus,

$$(a - x)^5 = a^5 - 5a^4x + 10a^3x^2 - 10a^2x^3 + 5ax^4 - x^5$$

Example 2. Let $n = -3$, then $n - 1 = -4$, $n - 2 = -6$ &c.

Hence a^n . . .	is a^{-3} . .	$= a^{-3}$
$na^{n-1}x$ . . .	$-3a^{-4}x$	$= -3a^{-4}x$
$\frac{n(n-1)}{2}a^{n-2}x^2$ . .	$\frac{-3 \times -4}{2}a^{-6}x^2$	$= +6a^{-5}x^2$
$\frac{n(n-1)(n-2)}{2 \cdot 3}a^{n-3}x^3$.	$\frac{-3 \times -4 \times -5}{2 \cdot 3}a^{-6}x^2$	$- = 10a^{-6}x^3$
$\frac{n(n-1)(n-2)(n-3)}{2 \cdot 3 \cdot 4}a^{n-4}x^4$	$\frac{-3 \times -4 \times -5 \times -6}{2 \cdot 3 \cdot 4}a^{-7}x$	$= +15a^{-7}x^4$

and so on.

$\therefore (a + x)^{-3} = a^{-3} - 3a^{-4}x + 6a^{-5}x^{-2} - 10a^{-6}x^3 +$ &c. And

$$(a + x)^{-3} = \frac{1}{a^3} - \frac{3x}{a^4} + \frac{6x^2}{a^5} - \frac{10x^3}{a^6} + \frac{15x^4}{a^7} - \&c.$$

$$(a + x)^{-3} = \frac{1}{a^3}\left\{1 - \frac{3x}{a} + \frac{6x^2}{a^2} - \frac{10x^3}{a^3} + \frac{15x^4}{a} - \&c.\right\}$$

But if x becomes $-x$ we would have for the expansion,

$(a-x)^{-3}$

$$= \frac{1}{a^3}\left\{1 - \left(-\frac{3x}{a}\right) + \frac{6x^2}{a^2} - \left(-\frac{10x^3}{a^3}\right) + \frac{15x^4}{a^4} - (-\text{\&c.}\right\}$$

$$= \frac{1}{a^3}\left\{1 + \frac{3x}{a} + \frac{6x^2}{a^2} + \frac{10x^3}{a^3} + \frac{15x^4}{a^4} + \text{\&c.}\right\}$$

To expand $(a+x)^{\frac{m}{n}}$ when $\frac{m}{n}$ is either a positive or negative fraction.

Let A, B, C, D, &c. represent the 1st, 2nd, 3rd, 4th, &c. terms respectively, and let $Q = \frac{x}{a}$, then will

$$(a+x)^{\frac{m}{n}} = (a+aQ)^{\frac{m}{n}} =$$

$$\underbrace{a^{\frac{m}{n}}}_{A} + \underbrace{\frac{m}{n}AQ}_{B} + \underbrace{\frac{\frac{m}{n}-1}{2}BQ}_{C} + \underbrace{\frac{\frac{m}{n}-2}{3}CQ}_{D} + \underbrace{\frac{\frac{m}{n}-3}{1}DQ}_{E} + \text{\&c.}$$

Or by reduction,

$$(a+x)^{\frac{m}{n}} = \underbrace{a^{\frac{m}{n}}}_{A} + \underbrace{\frac{m}{n}AQ}_{B} + \underbrace{\frac{m-n}{2n}BQ}_{C} + \underbrace{\frac{m-2n}{3n}CQ}_{D} + \underbrace{\frac{m-3n}{4n}DQ}_{E}$$

which is by far the most convenient practical form in the case of fractional and negative exponents, and differs but little from that in which the theorem was first exhibited by Sir Isaac Newton.

Example 1.—Express $\sqrt{(a+x)}$ in a series.

Here $\sqrt{(a+x)} = (a+x)^{\frac{1}{2}}$, $\therefore m = 1, n = 2$, and $Q = \frac{x}{a}$

Hence $a^{\frac{m}{n}} \quad . \quad . \quad . \quad . \quad = a^{\frac{1}{2}} \quad . \quad . \quad = a^{\frac{1}{2}} = A$

$$\frac{m}{n}AQ = \frac{1}{2} \times a^{\frac{1}{2}} \times \frac{x}{a} \quad = \frac{1}{2}\cdot\frac{x}{a^{\frac{1}{2}}} \quad . \quad . \quad = \frac{x}{2a^{\frac{1}{2}}} = B$$

$$\frac{m-n}{2n}BQ = \frac{-1}{4} \times \frac{1}{2}\cdot\frac{x}{a^{\frac{1}{2}}} \times \frac{x}{a} = -\frac{1}{2\cdot4}\cdot\frac{x^2}{a^{\frac{3}{2}}}$$

$$= -\frac{x^2}{8a^{\frac{3}{2}}} = C$$

$$\frac{m-2n}{3n}CQ = \frac{-3}{6} \times -\frac{1}{2\cdot4}\cdot\frac{x^2}{a^{\frac{3}{2}}} \times \frac{x}{a} = \frac{1\cdot3}{2\cdot4\cdot6}\cdot\frac{x^3}{a^{\frac{5}{2}}}$$

$$= +\frac{x^3}{16a^{\frac{5}{2}}} = D$$

$$\frac{m-3n}{4n}DQ = \frac{-5}{8} \times \frac{1\cdot3}{2\cdot4\cdot6}\frac{x^3}{a^{\frac{5}{2}}} \times \frac{x}{a} = \frac{1\cdot3\cdot5}{2\cdot4\cdot6\cdot8}\cdot\frac{x^4}{a^{\frac{7}{2}}}$$

$$= -\frac{5x^4}{128a^{\frac{7}{2}}} = E$$

and so on.

$$\therefore \sqrt{(a+x)} = a^{\frac{1}{2}} + \frac{x}{2a^{\frac{1}{2}}} - \frac{x^2}{8a^{\frac{3}{2}}} + \frac{x^3}{16a^{\frac{5}{2}}} - \frac{5x^4}{128a^{\frac{7}{2}}} + \text{\&c.}$$

$$= a^{\frac{1}{2}}\left\{1 + \frac{x}{2a} - \frac{x^2}{8a^3} + \frac{x^3}{16a^5} - \frac{5x^4}{128x^7} + \text{\&c.}\right\}$$

Example 2. Express the value of $\frac{c^2}{(c^2-x)^{\frac{1}{2}}}$ in a series.

Here $\frac{c^2}{(c^2-x)^{\frac{1}{2}}} = c^2(c^2-x)^{-\frac{1}{2}}$ $\therefore m = -1, n = 2$, and $Q = -\frac{x}{c^2}$

Hence $a^{\frac{m}{n}} = (c^2)^{-\frac{1}{2}} = \sqrt{(c^2)^{-1}} = \sqrt{\frac{1}{c^2}} = \frac{1}{c} = A$

$$\frac{m}{n}AQ = \frac{-1}{2} \times \frac{1}{c} \times -\frac{x}{c^2} = +\frac{1}{2}\cdot\frac{x}{c^3} = +\frac{x}{2c^3} = B$$

$$\frac{m-n}{2n}BQ = \frac{-3}{4} \times \frac{1}{2}\cdot\frac{x}{c^3} \times -\frac{x}{c^2} = +\frac{3}{2\cdot4}\cdot\frac{x^2}{c^5} = \frac{3x^2}{8c^5} = C$$

$$\frac{m-2n}{3n}CQ = \frac{-5}{6} \times \frac{3}{2\cdot4}\cdot\frac{x^2}{c^5} \times -\frac{x}{c^2} = \frac{3\cdot5}{2\cdot4\cdot6}\cdot\frac{x^3}{c^7} = \frac{5x^3}{16c^7} = D$$

$$\frac{m-3n}{4n}DQ = \frac{-7}{8} \times \frac{3\cdot5}{2\cdot4\cdot6}\cdot\frac{x^3}{c^7} \times -\frac{x}{c^2} = \frac{3\cdot5\cdot7}{2\cdot4\cdot6\cdot8}\cdot\frac{x^4}{c^9} = \frac{35x^4}{128c^9} = E$$

and so on.

$$\therefore c^2(c^2-x)^{-\frac{1}{2}} = c^2\left\{\frac{1}{c} + \frac{x}{2c^3} + \frac{3x^2}{8c^5} + \frac{5x^3}{16c^7} + \frac{35x^4}{128c^9} + \text{\&c.}\right\}$$

$$= c + \frac{x}{2c} + \frac{3x^2}{8c^3} + \frac{5x^3}{16c^5} + \frac{35x^4}{128c^7} + \text{\&c.}$$

Example 3.—Express the value of $\sqrt[3]{11}$ in a series.

Here $\sqrt[3]{11} = (8+3)^{\frac{1}{3}} = (2^3+3)^{\frac{1}{3}}$, $\quad m = 1, n = 3$

and $Q = \frac{3}{2^3}$

Hence $a^{\frac{m}{n}} = (2^3)^{\frac{1}{3}} = 2 = A$

$$\frac{m}{n}AQ = \frac{1}{3} \times 2 \times \frac{3}{2^3} = \frac{2\cdot3}{3\cdot2^3} = \frac{1}{2^2} = B$$

$$\frac{m-n}{2n}BQ = \frac{-2}{6} \times \frac{1}{2^2} \times \frac{3}{2^3} = -\frac{2\cdot3}{6\cdot2^5} = -\frac{1}{2^5} = C$$

$$\frac{m-2n}{3n}CQ = \frac{-5}{9} \times -\frac{1}{2^5} \times \frac{3}{2^3} = +\frac{1\cdot3\cdot5}{9\cdot2^8} - \frac{5}{3\cdot2^8} = D$$

$$\frac{m-3n}{4n}DQ = \frac{-8}{12} \times \frac{5}{3\cdot2^8} \times \frac{3}{2^3} = -\frac{3\cdot5\cdot8}{3\cdot12\cdot2^{11}} = -\frac{5}{3\cdot2^{10}} = E$$

$$\frac{m-4n}{5n}EQ = -\frac{11}{15} \times -\frac{5}{3\cdot2^{10}} \times \frac{3}{2^3} = +\frac{3\cdot5\cdot11}{3\cdot15\cdot2^{13}} = \frac{11}{3\cdot2^{13}} = F$$

and so on.

$$\therefore \sqrt[3]{11} = 1 + \frac{1}{2^2} - \frac{1}{2^5} + \frac{5}{3\cdot2^8} - \frac{5}{3\cdot2^{10}} + \frac{11}{3\cdot2^{13}} - \text{\&c.}$$

Ex. 4. $\sqrt{a-x^2} = a - \frac{x^2}{2a} - \frac{x^4}{8a^3} - \frac{x^6}{16a^5} - \text{\&c.}$

Ex. 5. $\sqrt[3]{x+y} = x + \frac{y}{3x^2} - \frac{2y^2}{3\cdot6x^5} + \frac{2\cdot5y^3}{3\cdot6\cdot9x^8} - \frac{2\cdot5\cdot8y^4}{3\cdot6\cdot9\cdot12^{11}}$

Ex. 6. $(ax)^{\frac{2}{3}} = a\left\{1 + \frac{2x}{3a} + \frac{x^2}{3^2a^2} + \frac{4x^3}{3^4a^3} + -\frac{7x^4}{3^5a^4} + \text{\&c.}\right\}$

Ex. 7. $\sqrt{a^3 - a^2x^2} = a\left\{1 - \frac{1}{2}x^2 - \frac{1}{2\cdot4}\cdot x^6 - \frac{1\cdot3}{2\cdot4\cdot6}\cdot x^6\right.$

$$\left. - \frac{1\cdot3\cdot5}{2\cdot4\cdot6\cdot8}\cdot x^8 - \text{\&c.}\right\}$$

Ex. 8. $(a^2 - x^2)^{\frac{3}{2}} = \frac{1}{a^{\frac{1}{2}}}\left\{a^2 - \frac{3x^2}{2^2} - \frac{3x^4}{2^5a^3} - \frac{5x^6}{2^7a^4}\right.$

$$\left. - \frac{5\cdot9x^8}{2^{11}a^6} - \text{\&c.}\right\}$$

Ex. 9. $\sqrt[3]{9} = 2 + \frac{1}{3\cdot2^2} - \frac{1}{3\cdot6\cdot2^4} + \frac{5}{3\cdot6\cdot9\cdot2^7}$

$$- \frac{5\cdot8}{3\cdot6\cdot9.12\cdot2^{10}} + \text{\&c.}$$

To find any term in the expansion of $(a+x)^n$, when n denotes any number whatever, integral or fractional, positive or negative.

If we examine the general formula, we shall readily perceive that a certain relation subsists between the coefficients and exponents of each term in the expanded binomial and the place of the term in the series, thus:

The first term is a^n which may be put under the form a^{n-1+1}

Second, $na^{n-1}x \quad . \quad . \quad . \quad . \quad . \quad na^{n-2+1}x^{2-1}$

Third, $\frac{n(n-1)}{1\cdot2}a^{n-2}x^2 \qquad \frac{n(n-3+2)}{1\cdot(3-1)}a^{n-3+1}x^{3-1}$

Fourth, $\frac{n(n-1(n-2)}{1\cdot2\cdot3}a^{n-3}x^3 \quad \frac{n(n-1)(n-4)+2)}{1\cdot2\cdot(4-1}a^{n-4+1}x^{4-1}$

Fifth, $\frac{n(n-1)(n-2)(n-3)}{1\cdot2\cdot3\cdot4}a^{n-4}x^4 \quad \frac{n(n-1)(n-2)(n-5+2)}{1\cdot2\cdot3\cdot(5-1)}a^{n-5+1}x^{5-1}$

and so on.

$\therefore$ The pth term will be

$$\frac{n(n-1)(n-2)(n-3) \quad . \quad . \quad . \quad n-p+2)}{1\cdot2\cdot3\cdot4 \quad . \quad . \quad . \quad . \quad . \quad (p-1)}a^{n-p+1}x^{p-1}$$

This is called the general term, because by giving to p the values 1, 2, 3, 4, . . . we can obtain in succession the different terms of the series for $(a+x)^n$.

Example 1.—Required the 5th term of the expansion of $(a-b)^9$.

Here $\left.\begin{array}{l} n = 9 \\ p = 5 \end{array}\right\}$ $\therefore n-p+2 = 6 \quad . \quad n-p+1 = 5$

$\qquad\qquad p-1 = 4$

Substituting these values in the general expression, there results

$$\frac{9\cdot8\cdot7\cdot6}{1\cdot2\cdot3\cdot4}a^5x^4 = 126\,a^5x^4$$

HISTORY.

CHAPTER XXV.

RECAPITULATION AND CONCLUSION.

Our labours in the elucidation of the theoretical and practical branches of the subject of Civil History, have now drawn to a close. In the theoretical or introductory part of the course, we endeavoured, in the first place, to enumerate the various sources from which it was possible to extract historical information; in the second place, to show the manner in which the intellect must operate upon these sources, in order to elaborate from them historical knowledge at once true and valuable. We traced historically the rise and progress of the sources of chronology, geography, and language, as the most ready means of conveying an accurate conception of the nature and objects of these sciences. Time and space are the theatre within which the drama of real life is incessantly performing, and to comprehend it aright—to be able to view it from all sides—it is necessary to lift our eyes to that wider portion of that extensive bulk of time and space, of which it only occupies a portion. Just views of the nature and varieties of language are equally indispensable to the historical student, seeing that it is not merely the medium of the communication of men's thoughts, but an important and indispensable instrument in the process of thinking.

For the illustration of the practice of historical investigation, with which these preliminary expositions were followed up, we selected that portion of civil history—that is, of the history of organized society, of men living under a government—which relates to Europe, from the foundation of the Roman state down to our own age. It was necessary to a full development of the influences which alternately promoted and retarded the development of social institutions, to go back to more remote ages. We had to trace the revolutions of empire, and the forms of thought enclosed under them in states belonging to an earlier period of history than Rome—and more especially in Egypt, Greece, and Judea. Having traced the progress by which Europe became united, along with great part of Africa and Asia, under one common government, the central seat of which was at Rome or Byzantium, we next traced the resolution of that empire in Europe into a feudal anarchy, and the emerging from that amorphous condition of society, of a system of national governments, united among themselves by common necessities, still more by the kindred character of their citizens in opinions, customs, and institutions; and each within itself working out, under the modifying influence of differing circumstances, the great practical problem of the true relation of the governors to the governed.

Our delineations of social institutions can elucidate little more than the general results; they will, notwithstanding, be, we apprehend, of much use in methodising and arranging the information gleaned from the writers of any age comprehended in it, and in precluding misinterpretation of their phraseology, and rash inferences from their statements. Without them it is a dry and lifeless catalogue, without it they are *ignes fatui,* which "lead to bewilder, and dazzle to blind."

The first and the most important fact demonstrated by such a review of history is the extensive and pervading influence exercised upon men's minds by the fortunes, actions, and thoughts of those who lived before them. The mind has a self-creative power which, out of the influences of events, forms a character for itself—a congeries of opinions, rules of action deduced from them, and habits contracted by the observance of these rules. The peculiarity of our nature, to which this is owing, was pointed out and illustrated in the chapter devoted to the discussion of the laws of evidence, and again in that which treated of the laws of language. It is the result, in the first place, of the necessity under which we lie of piecing out the fragmentary knowledge we derive, directly or indirectly, from the impressions of sense, by supplementary opinions entertained upon the authority of others: and in the second place, that in the process of following out a train of consecutive reasoning we are constantly and unavoidably in the habit of substituting words, and even phrases, in the place of ideas, just as in mathematical ratiocination we substitute algebraical exponents for figures or numbers. The exercise of thought does not pre-suppose a full consciousness of the operation. Hence, in the deductions of science, and in the practical reasoning which regulates our actions, are intermingled many conventional phrases which we have adopted with but a vague conception of their import from others, and which, without our being aware of it, give a tone and colouring to our opinions. It is this that makes the study of history so important to the student of morals, of politics, and even of religion.

By morals we mean those conventional rules of action which, without being embodied in laws, or enforced by authority, regulate the conduct of men in society. No man forms such a code for himself. Some maxims he hears enunciated by the guardians of his childhood, and adopts from reverence to them. At that pliant age habits are easily contracted which become ineffaceable. Other maxims he elaborates from his experience—prescriptions of the means of attaining pleasureable sensations, or of avoiding painful. Others again he hears laid down by those with whom he stands upon an equal footing, and adopts after more or less mature and acute investigation. The principles of our nature which enforce conformity to this voluntary law are, that which makes us dependent upon the good will and co-operation of our fellows, and that which makes us take pleasure in their good opinion. Men living in the same community mutually defer to the views and prejudices of each other, for the sake of maintaining a good understanding, of giving and receiving assistance, of interchanging pleasing flattery. The opinions of all men, whether they be self-formed or adopted from others, take their character from the position and circumstances of the parent mind when set athinking; they are, from the finite nature of man, a blended mass of truth and error. There is an eternal well-spring of truth in the human breast constantly infusing a portion of the former; there is a want of power to distinguish accidental from essential phenomena constantly introducing the latter. The most fruitful source of error is confined and partial knowledge. The man who has never travelled beyond his own village is most ingrained in error; he can conceive no condition of society different from that in which he exists; he can conceive no possible error in the opinions which are the currency of his society. He whom business or other relations has forced to mingle among more than one community of the same country, is shaken in some slight degree out of his unquestioning and apathetic state. He who has been brought into collision with men of a different nation is still further awakened. The first question asked of itself by the mind is the first step to truth. Now, history does for even the laggard in his own first home what travel does for more active natures, and it immeasureably extends the field of enquiry even to the most restless and unwearied of human beings. But history does not cease its beneficial influence when it has roused men to canvass the soundness of conventional opinions; it puts into their power the means of testing their validity, of establishing their truth or falsehood; it enables us to trace back opinions to their first promulgators, to ascertain the modifications they have undergone in the process of tradition, to examine the circumstances under which they were first formed. We can thus see whether they rest upon hasty and superficial views, or upon a large and comprehensive induction of facts. History furnishes us at least with means of forming correct moral opinions, and that is half the battle, for to the constitution of the moral man there are two requisites—first, that his intellect be as far as possible purged from error; second, that by long practice in subduing and regulating his emotions, to have made good and beautiful thoughts and actions, familiar and easy, and have unrooted those of a contrary character, which all, in the period of life during which the growth of our emotional outruns the growth of our intellectual nature, unavoidably contract.

The same good service which extensive and accurate historical knowledge affords in morals, it affords also in the field of politics. Government is a purely experimental art and science. Men have been labouring incessantly since the first dawn of society to obtain institutions that shall conduce in the greatest possible degree to the general and individual welfare. The incessant changes in all states which have retained any degree of freedom, which afford such a fertile topic of declamation to shallow thinkers, are the necessary consequence of this instinct. Men are not to be blamed for changing when they feel themselves uneasy, nor even for constant and ill-calculated changes in the first outset of society. They are only blameable when they continue to act blindly upon the spur of impulse, without taking lessons from the experience of the past, when the page of history is in their hands. At no time can we stand still: progression is the law of our nature. But with the records of our ancestors accessible to us, we ought to take warning by such of their steps as have led them into evils, and to persist in those which have led to more fortunate results. The broad lessons of the period of history through which I have led your steps in the illustrative portion of my remarks are simple and important. We have encountered societies constructed upon true principles: one class sprung from a sort of alliance offensive and defensive among all the citizens of a certain community.

These have generally been found deficient in cohesive power. Proud spirits yielded reluctantly to the sway of others; or a quiet people acquiesced in the ascendancy of a few leading families, until those, puffed up by the deference paid to them, began to abuse the power entrusted to their hands. Either process resolved the little state into anarchy; and the reins of government, after being for a while bandied about between the many and the few, were seized by one hand, in whose usurpation the many acquiesced for the sake of tranquillity. The other class sprung, either, as in the case we have been contemplating, after an experimental trial of the former, or from the beginning, from the subjection of the many to the will of a few. In a society thus constituted, the healthy exercise of the intellect and imagination, and under their influence of the will, was necessarily restrained, if not wholly debarred. The recompence for this negation was peace, but peace thus obtained was soon found to be elusory. An all-wise and all-good Being alone could safely be entrusted with the power committed to the sovereign of such states. Beings, from their nature of limited capacity, and from their position in an infant world of still more limited experience, standing to each other in the relation of master and subject, mutually corrupted each other. The former became overweening and unjust: the latter became unreflecting and feeble. The monarch ruled for his own purposes, and the limit of his exaction and oppression was his slaves' capacity of endurance. They encroached till nature could endure no more, and their rising was that of madmen, not of calculating beings. The anarchy into which it was the tendency of despotism, as well as of democracy and aristocracy to resolve itself, was the more awful of the two. The lust of power doth grow with what it feeds on; and to this law of human nature is attributable the desire, the meaning of which is continually recurring in every page of history, of the master of one community to add others to his subjects. The great oriental empires were the result of this instinct. In Rome we have an example of a state forced outwardly into the conquering career before it had arrived internally at the monarchical. To this we are indebted for, on the one hand, something akin to the cohesive authority which kept together the discordant elements of despotic states, and made them available for external conquest; and to the development of a systematic code, defining, and serving as a guide to those whose duty it was, to enforce the mutual rights of individuals, such as never could spring up in a state where one alone was master, and all the rest his servants—where the bosom of the sovereign was the capricious fountain of what served as a substitute for law. To this peculiarity of the Roman state we owe the establishment of the municipal system, the theory of which was:—that the citizens within each district managed their own local affairs; that the central authority exercised an appellate jurisdiction and revisionary power in internal affairs, and managed all transactions with foreign powers. The weakness of the Roman constitution, which occasioned it ultimately to dissolve in anarchy as smaller states had done before it, was the incompleteness of the establishment of the popular principle. In the majority of the municipalities the functions of government were reposed, not in the citizens, but in the hands of a few virtually irresponsible individuals. The populace of Rome stood to the other communities of the state in the same relation that the despot did to his subjects, and it was as incompletely organized as the cities it had subdued. It was exposed at once to the corrupting influences which had their origin in both forms of government.

When anarchy is introduced the strongest is the master: in the disjointed empire of Rome the warlike half-savages from the north asserted their superiority over the enervated citizens. But none of them was sufficiently elevated above his fellows to seize or retain the sole supremacy. In Europe the Roman empire split up into a number of petty dynasties. But the system of law, and the municipal institutions survived the disruption—the latter gaining, instead of losing strength. The practice of government did not retrograde. The sense of popular power and right grew stronger in some of the national governments, which developed themselves out of the fragments of Roman sway. In all of them a national spirit of independence sprung up, which was more healthy than the subordination of all nations to one city. A proud consciousness of equality and independence of each other, was kept up among the European states, at the same time that the uniformity of their institutions, morals, and religion, kept a certain degree of brotherly feeling among them. Circumstances dwelt upon at some length in last chapter developed the system of representative government in England in connection with monarchy. Other circumstances displayed the sufficiency of this representative system in America to sway the destinies of a nation even after the monarchical ingredient had been extracted from it. The less fortunate nations of Europe, in which popular rights had been diminished or extirpated in the process of establishing a national government, were struck with the advantages to be derived from it, and the necessities of their governments have from time to time afforded them opportunities of making the experiment. This has been the business of the age in which we live: the unavoidable tendency of society to introduce the representative principle into every state, and into every function of government. Self-government is what the people of all nations of European origin in either hemisphere are struggling to attain. In one country alone have they been completely successful: in many the autocrats have maintained their ground, and to a superficial gazer even bettered their position. But to those who take a more comprehensive survey, and whose eye can penetrate beneath the surface, their days are numbered. In this country, the real supreme power of the state has for more than a century been transferred from the crown to those who possess the elective franchise. In France, Holland, Spain, Portugal, and Belgium, the crown depends upon the popular will: the sovereign stands alone among the people. And even in the monarchical states men are now quite aware that the sovereign is but a name under which clever politicians exercise authority. Under every form of government it is, and has been, *opinion* that exercised sovereign sway. Whatever *opinion* could enlist the majority of the physical force in a country has been established. What the majority of the thinking, arms-bearing men of a country decidedly and coolly believe, is or ought to be its form of government, ever has been and ever will be its government. The veriest despot that ever existed was a despot only so long as the physical strength of the country believed that he was so of right, or that it was for their interest he should continue to be so. The *prestige* of the monarchical principle is clearing away from the opinions of men; the autocrats may struggle for a time longer—beyond the endurance of the present generation, for in a question of this kind, generations are as moments or less; but they are doomed. They are fighting a battle which must terminate in defeat. Society is advancing to the entire and universal adoption of the representative system. The unconsciousness or the voluntary disregard of this truth is one great source of the confusion which pervades society. Another source is a struggle going on simultaneously of which men are not yet equally aware. This is the demand of all classes of society to be admitted within the pale of civil society. At no period of history, even in the freest states, has the number of citizens been co-extensive with the number of denizens. The unprivileged classes have continued to advance both in intelligence and in power. They have everywhere in Europe burst the bands of personal slavery. The last fetters of feudality are seen in Russia dropping from their limbs. They are on all sides demanding in addition to this personal emancipation, admission to participate in that self-government which it is the aim of the privileged classes to attain for themselves. They declare that the representative system is incomplete without them:—That if the middle classes cannot allow kings and nobles to act for them, neither can the unenfranchised safely trust the middle classes to legislate for them. This contemporary struggle is apparently even more distant from arrangement than the other. The United States of America, in advance of all other countries on the other branch of the question, lags behind them here. Millions of her working-classes are not only devoid of political privilege but of personal freedom. The issue of this controversy, let it come when it may, is as certain as that of the other. Nature does nothing by starts or capriciously. When we have watched, for a sufficient length of time, the great stream of tendency, we can calculate at least its future direction if not the exact period of its termination. Slavery has vanished from Europe. The unprivileged masses are beginning to act upon deliberate calculations, and make a specific aim. We no longer witness armless insurrections like those of the Jacquerie in France during the feudal anarchy, or of the war of the peasants in Germany in the time of Luther. But there is everywhere heard a demand for admission to the privilege of the electoral franchise—a demand never wholly intermitted, and which every time it swells more noisily upon the ear, gains in that deep *soutenute*, which denotes inflexible intensity of purpose. Their demand must be granted at last. When, will depend more upon the circumstances of each individual state than upon nice calculations of the safest and the most expedient time. It is in vain to say, they must be educated before they are admitted to the franchise: when the incidence of taxation or some other class grievance becomes too heavy to be longer borne, when the minds of a sufficient majority of the already unenfranchised classes are familiarized with the idea of extending the right to all, it will be boldly demanded, feebly refused, and reluctantly conceded. The danger will be, not in the extension of the franchise, but in the excited tempers occasioned by the struggle for it. Of the two re-

quisites for the right exercise of it, knowledge sufficient for the purpose exists already; the habits without which knowledge is nothing, are more dubious, but even they can only be shown to exist by exercise—perhaps can only be learned by exercise. To conclude, come the transition when it will, and under whatever auspices—in the whisper of a daybreak breeze or in the roar of a thunder-storm—it is coming. In every European state representative institutions will be introduced—the representative principle will pervade every institution of the state—the representative principle will embrace all the denizens of each state. How these constitutions will work is another question, and depends, in part at least, upon different influences. In proportion to the advance of men in knowledge, and the influence of that knowledge in correcting their habits and purifying their sentiments, will the result be.

We have said that the study of history is calculated to furnish important results in the matter of religion as well as in politics and morals. Religion consists of three branches:—the devotional sentiment, theological knowledge, and practical influence. The sentiment seems to exist with more or less intensity, in all men: but like all our sentiments if unassociated with knowledge, it is apt to cling to unworthy objects and to catch contamination from them. Sound theological knowledge, by the fruit of God's gracious meeting the throes and struggles of the finite creature to comprehend his blessed and benevolent Creator, more than half-way, by his Revelation—teaches us to comprehend as far as our inadequate powers enable us, the attributes of the divinity, the relation in which we stand to him, the duty we owe him. It teaches us that grateful veneration is his due—resignation to his will, preservation of a pure soul, and perseverance in good actions. Theology does not teach us what is good in action, but it teaches us that the practice of what is good is one of the worthiest and most acceptable acts of adoration if performed with that view. From this source flows the beneficial practical influence of religion upon man. It inspires him with a feeling of equable dignified happiness, for in proportion as he learns to know God, does he learn to repose unqualified unintermitting confidence in his goodness. By habitual contemplation of the Divinity and his works, the soul catches a reflex of their glory, as the face of Moses contracted a brightness more than his kinsmen could bear, from the converse on mount Sinai. The dispositions acquire a new motive to good actions from the habit of regarding them as an acceptable act of worship, and the most trifling duties gain in importance from such a habit of thought. Above all there is in true religion an undying power which no other good influence possesses: it teaches that even fruitless efforts, if honest, are not without their reward, and that the reward of persevering renewal of them, is ultimate success. Now the study of history tends in two ways to keep clear our religious conceptions, the well-spring which must be clear and untroubled if the rest is to be available. In the first place, in so far as Revelation is concerned, I have again and again had occasion to remark that our imperfect humanity sees divine light through its own discolouring medium. It therefore has always been, and must continue to be, that errors will spring up to the end of time. Every one who takes in trust from a fellow-being, receives a distorted image, and distorts it more in the reception. There is a double use in turning back to the first authorities: we receive the truth more pure, and by following down the stream of history, we can trace the origin and development of each error, the surest way to disarm it of the power of doing mischief. There is another way in which a study of history is of use in this respect. There are many phrases in the original Scriptures which have verbal and literal counterparts in our own language of the present day. But, owing to the change in mens' physical condition and metaphysical opinions, the imports of those phrases in the old time and now, differ materially. A knowledge of the circumstances of society and the theoretical opinions of men in that old time, is therefore necessary in order to guard us against misconceptions which have in all times been the fruitful source of mystical absurdities. The second way in which history is available for the purpose of keeping clear our religious conceptions is by teaching us to discriminate between priestcraft and religion. Religion is the spiritual influence upon the inner man: priestcraft is the assumption of the external appearance of religion in order to give the actor influence, and thereby authority over the minds of man. Wherever you find the forms and social organization introduced as props and helps to religion, attaining an undue ascendancy, be assured priestcraft is taking the place of religion; and throughout the whole of history there is not one instance of such a substitution being effected without injuring and degrading mankind.

In this way does the study of history tend to promote sound and rational views in morals, politics and religion, to strengthen them for their great task of enabling men to live peaceably together. It is only in the peaceful state of society enjoyed under their shadow, that man can tranquilly and effectually abandon himself to the pursuit of knowledge. But it is not in this indirect manner alone that the study of history contributes to the diffusion of knowledge. The faculties called into exercise by historical investigation, and strengthened and developed by the process, are the most important we possess. The study of history is a practical preparation for other pursuits. There is not a field of human activity in which the habit of weighing and discriminating evidence which it corroborates will not be found useful. It instigates us at every turn to enter upon scientific enquiries of the most various kinds, in order that we may more fully comprehend and estimate its narratives. It is the best antecedent of metaphysical inquiry, for, important as the results are of a habit of discerning the phenomena of our own minds, there is no habit more deleterious, if contracted before the mind is well stored with a knowledge of external facts, before the faculties which are the objects of observation have to a certain extent developed themselves by exercise.

ON THE AURORA BOREALIS.

BY ALEX. VON HUMBOLDT.

Terrestrial magnetism, the electro-dynamic forces which have been calculated by the able Ampére, stands at the same time in intimate relationship with the Earth or Northern-Lights [Aurora borealis], as with the internal and external temperature of our globe, whose magnetic poles must be regarded as poles of cold. If Halley, some 128 years ago, gave it out as a mere bold conjecture, that the northern light was a magnetic phenomenon, Faraday's brilliant discovery of the evolution of light through magnetic power has raised that conjecture to the rank of an empirical certainty. There are heralds or harbingers of the northern lights. In the course of the day on which the lights are to appear, irregular horary movements of the magnetic needle usually indicate an interruption of equilibrium in the distribution of the terrestrial magnetism. When this disturbance has attained a great intensity, the equilibrium of the distribution is restored by a discharge, accompanied with an evolution of light. "The northern light itself is not, therefore, to be regarded as an external cause of the disturbance, but rather as a terrestrial activity raised to the pitch of a luminous phenomenon, one of the sides of which is the light, the other the oscillations of the needle."* The splendid phenomenon of coloured northern lights is the act of discharge, the conclusion of a magnetic storm; in the same way as, in the electrical storm, an evolution of light—lightning—indicates the restoration of the disturbed equilibrium in the distribution of electricity. The electrical storm is usually limited to a small space, beyond which the state of the electricity remains unchanged. The magnetic storm, on the contrary, reveals its influence on the march of the needle over large portions of continents, as Arago first observed, and far from the place where the developement of light is visible. It is not improbable that, as in the case of heavily charged and threatening clouds, and of frequent transitions of the atmospheric electricity into opposite states, it does not always come to discharges by lightning, so also may magnetic storms produce great disturbances in the horary motions of the needle over extensive circles, without there being any necessity for explosions, for luminous effusions from the pole to the equator, or from one pole to another, in order to restore the equilibrium.

He who would have all the particulars of the phenomenon embraced in one picture, should have the origin and course of a complete appearance of the northern lights set before him. Deep on the horizon, nearly in the situation where it is intersected by the magnetic meridian, the heaven, up to this moment clear, grows black. There is a kind of hazy bank or screen produced, which rises gradually, and attains to an altitude of from 8 to 10 degrees. The colour of the dusky segment passes over into brown or violet. Stars are visible in it, but they are seen as in a portion of the sky obscured with dense smoke. A broad bright luminous arc or seam, first white, then yellow, bounds the dusky segment; but as the brilliant bow arises later than the smoky-grey segment it is impossible, according to Argelander, to ascribe the latter to the effect of mere contrast with the bright luminous border. The

* The dipping needle comports itself very nearly as an atmospherical electrometer, whose difference in like manner shows the increased tension of the electricity before it has risen to such a height that a spark is elicited. —*Dove.*

highest point of the luminous arc, when it has been carefully measured, has usually been found to be not exactly in the magnetic meridian, but to vary between 5 and 18 degrees from it, towards the side on which the magnetic declination of the place of observation lies. In high northern latitudes, very near the north pole, the smoky-looking spherical segment appears less dark ; sometimes it is even entirely absent. In the situation, too, where the horizontal force is least, the middle of the luminous arc is seen to depart farthest from the magnetic meridian.

The luminous bow, in constant motion, flickering and changing its form incessantly, sometimes remains visible for hours before anything like rays and pencils of rays shoot from it, and rise to the zenith. The more intense the discharges of the northern lights, the more vividly do the colours play from violet and bluish-white, through every shade and gradation, to green and purplish-red. In our ordinary electricity produced by friction, in the same way, the spark first becomes coloured when the tension is high, and the explosion is violent. The magnetic fiery columns shoot up at one time singly from the luminous arch, even mingled with black rays, like thick smoke ; at another, many columns arise simultaneously from several and opposite points of the horizon, and unite in a flickering sea of flame, to the splendour of which no description can do justice, and whose luminous waves assume another and a different shape at every instant. The intensity of the northern light is at times so great, that Lowenorn perceived its oscillations, in bright sunshine, on the 29th of January, 1786. The motion increases the brilliancy of the phenomenon. Around the point of the vault of heaven which corresponds with the direction of the dipping needle, the rays at length collect together, and form the corona or crown of the northern lights. This surrounds the summit, as it were, of a vast canopy, the dome of heaven, with the mild radiance of its streaming but not flickering rays. It is only in rare instances that the phenomenon proceeds the length of forming the corona completely. With its appearance, however, the whole is at an end. The rays now become rarer, shorter, less intensely coloured. The crown and the luminous arches break up. By and bye nothing but broad, motionless, and almost ashy-grey, pale gleaming fleecy masses, appear irregularly dispersed over the whole vault of heaven ; these vanish in their turn, and before the last trace of the murky fuliginous segment, which still shows itself deeply on the horizon, has disappeared. Of the whole brilliant spectacle, nothing at length remains but a white delicate cloud, feathered at the edges, or broken up, as a cirro-cumulus, into small rounded masses or heaps, at equal distances.

This connection of the polar light with the most delicate cirrus-clouds, deserves to be particularly mentioned ; inasmuch as it shows us the electro-magnetic evolution of light as part of a meteorological process. The terrestrial magnetism here manifests itself in its effects upon the atmosphere, in a condensation of the watery vapour which it holds dissolved. The observations, made in Iceland by Thienemann, who regards the cirro-cumulus, or divided fleecy clouds, as the substrate of the northern lights, have been confirmed in later times by Franklin and Richardson, near the North American magnetic pole, and by Admiral Wrangel, on the Siberian coasts of the icy sea. All observed "that the northern lights sent forth the most brilliant rays when masses of cirro-stratus floated in the upper regions of the atmosphere ; and when these were so thin that their presence was only known by the formation of a halo about the moon." These light clouds occasionally arranged themselves, by day, in the same manner as the rays of the Aurora, and had the same effect as these in disturbing the magnetic needle. After a grand nocturnal display of the northern lights, the same streaks of clouds that had been luminous over night, were discovered in the morning arranged in the same manner.* The apparently converging polar zones of clouds (streaks of clouds, in the direction of the magnetic meridian), which constantly attracted my attention in the course of my travels on the lofty platforms of Mexico, as well as in Northern Asia, belong apparently to the same group of diurnal phenomena.†

Southern lights have been frequently seen in England by that able and diligent observer, Dalton ; northern lights in the southern hemisphere, as low as 45° of latitude (Jan. 14, 1831). In instances that are not very rare, the magnetic equilibrium is disturbed at both poles simultaneously. I have distinctly stated that northern polar lights are seen within the tropics, even as far south as Mexico and Peru. It is necessary to distinguish, however, between the sphere of a simultaneous apparition of the phenomenon, and the zone of the earth in which the phenomenon is displayed almost every night in the year. As each observer sees his own rainbow, so also, doubtless, does he see his own polar light. A great portion of the earth engenders the radiating Light-phenomena at the same time. Many nights can be mentioned in which it was observed simultaneously in England, in Pennsylvania, in Rome, and in Pekin. When it is maintained that the northern lights decline with the decrease of latitude, this must be understood as referring to magnetic latitude, measured from the magnetic pole. In Iceland, Greenland, and Newfoundland, on the banks of the Slave lake, and at Fort Enterprise (in North Canada), the Aurora is lighted up, at certain seasons, almost every night, and with its shifting, shivering rays, performs its "merry dance" through the sky, as the natives of the Shetland Islands term it. Whilst in Italy the northern light is a great rarity, it is seen with extreme frequency in the latitude of Philadelphia (39° 57′ N.L.), in consequence of the southern position of the American magnetic pole. But in the districts of the new continent, and also of the shores of Siberia, which are remarkable for the frequency of the phenomenon, there occur what may be called especial regions of the northern lights—longitudinal zones in which they are peculiarly splendid. Local influences are, consequently, not to be overlooked. Wrangel observed their brilliancy decline as he left the shores of the icy sea, about Nijne-Kolymsk, behind him. The experience of the Northern Polar Expedition seems to indicate that the evolution of light is not greater in the immediate vicinity of the magnetic pole than it is at some distance from this spot.

What we know of the altitude of the northern light is based on measurements, which, by reason of the incessant oscillations of the luminous rays, and the consequent uncertainty of the parallactic angle, cannot be greatly depended on. The conclusions come to (not to speak of older estimates) vary between several miles and three or four thousand feet. It is not improbable that the northern light is at very different distances at different times. The latest observers are disposed to connect the phenomenon, not with the outer limits of the atmosphere, but with the region of the clouds itself; they even believe that the northern streamers may be moved by winds and currents of air, if the luminous phenomenon, by which alone the existence of the electro-magnetic emanations becomes obvious to us, be actually connected with material collections of vesicular vapour, or, to speak more correctly, penetrates these collections, darting over from one vesicle to another. Sir John Franklin saw a streaming Aurora on Bear Lake, which he believed illuminated the under side of the stratum of cloud ; whilst Kendal, who had the watch through the whole of the night, and never lost sight of the heavens for a minute, at the distance of but $4\frac{1}{2}$ geographical miles, observed no luminous phenomenon whatsoever. The statement, repeated several times of late, to the effect that streamers of the northern light have been observed close to the ground, and between the observer and a neighbouring height, is one of those points, which, like lightning and the fall of fire-balls, is exposed to the manifold dangers of optical deception.

Whether or not the magnetic storm, of which we have just quoted a remarkable example of local circumscription within very narrow bounds, has the noise, besides the light, in common with the electrical storm, is now rendered extremely doubtful, since the testimony of the Greenland sledgers, and the Siberian fox-hunters, is no longer taken unconditionally. The northern lights have become more silent since they have been examined more carefully with the eye and the ear. Parry, Franklin, and Richardson, near the north pole ; Thienemann, in Iceland ; Gieseke, in Greenland ; Lottin and Bravais, at the North Cape ; Wrangel and Anjou, on

* Parry saw a great Aurora continue through the day. Something of the same kind was seen in England, 9th Sept., 1827. At mid-day a luminous arch, 20° high, and rays shooting from it, were perceived after rain, in a part of the heavens that had become clear.

† After my return from my American travels, I described the cirro-cumulus cloud,—when it appears very regularly divided into round masses as if by the agency of repulsive forces—under the name of polar streaks (bandes polaires), because their perspective point of convergence is mostly in the magnetic meridian in the first instance, so that the parallel rows of cumuli follow the magnetic meridian. One peculiarity of this enigmatical phenomenon is, the swaying hither and thither of the point of convergence. Usually the streaks are only completely developed in one region of the sky, and in their motion they are seen directed first from south to north, and then gradually veering round from east to west. I cannot ascribe the advance of the zones to any change in the quarter of the wind in the superior strata of the atmosphere. They arise when the air is extremely calm and the heaven is particularly serene, and under the tropics are far more common than in the temperate and frigid zones. I have observed the phenomenon among the Andes, when I was at the height of 14,000 feet above the level of the sea, as well as in Northern Asia, in the plains of Krasnojarski, southward from Buchtarminsk, and in both instances so much alike, that the natural process in virtue of which it takes place must be regarded as one of very extensive prevalence. In an exhibition of south polar streaks of very delicate clouds, which Arago observed by day on the 23d of June, 1845, at Paris, dark rays shot upwards from an arch which was directed from east to west.—*Humboldt.*

the shores of the icy sea, have, altogether, looked at thousands of northern lights, yet never heard any noises. If this negative testimony be not admitted against two positive witnesses, Hearne, at the mouth of the Coppermine river, and Henderson, in Iceland, it must still be remembered that Hood heard the same noises—as of musket balls shaken rapidly together, and slight cracklings, during the occurrence of the northern lights, indeed, but also on the following day, when there was no Aurora in the heavens; and then it must not be forgotten, that Wrangel and Gieske were firmly convinced that the noises heard, were owing to contractions of the ice and crust of snow, in consequence of a sudden cooling of the air. The belief in a cracking noise did not exist among the people, but with learned travellers, and in this way:—the flashing of electricity in attenuated atmospheres having been known from an early period, the northern light was forthwith declared to be an effect of atmospheric electricity, and then the noises were heard that ought to have been heard. Recent experiments with the most delicate electrometers, however, contrary to all expectation, have given merely negative results: the state of the aerial electricity has not been found altered during the prevalence of the most brilliant Aurora.

All the three manifestations of force of the terrestrial magnetism—Declination, Inclination, and Intensity, on the contrary, are affected at once by the northern lights. In one and the same night, and from hour to hour, the Aurora affects the same end of the needle differently, now attracting it, now repelling it. The assertion that the facts collected by Parry at Melville Island, near the magnetic pole, lead to the conclusion that the northern lights do not disturb the needle, but rather have a "calming effect" upon it, is completely contradicted by a more careful perusal of Parry's own Journal, by the beautiful observations of Richardson, Hood, and Franklin, in North Canada, and, more lately still, by Bravais and Lotten in Lapland. The process in the northern lights is, as we have above observed, the act of an equilibrium disturbed. The effect upon the needle varies according to the measure of force in the explosion. It was only unobservable at the nocturnal winter station at Bosekop, when the luminous phenomenon showed itself very feebly and deep on the horizon. The upshooting radiate cylinders of the northern light have been aptly compared to the flame which, in the closed circuit of the Voltaic pile, arises between two charcoal points at a distance from one another, or, according to Fizeau, between a silver and a charcoal point, and to that which is drawn or thrown off from the magnet. This analogy at all events renders superfluous the assumption of those metallic vapours in the atmosphere which some natural philosophers have imagined as the substrate of the northern lights.

If the luminous phenomenon which we ascribe to a galvanic current, *i. e.* a motion of electricity in a circuit returning into itself, be designated by the indefinite name of the Northern light, or the Polar light, nothing more is thereby implied than the local direction in which the beginning of a certain luminous phenomenon is most generally, but by no means invariably, seen. What gives this phenomenon its greatest importance is the fact which it reveals, viz., that the EARTH IS LUMINOUS; that our planet, beside the light which it receives from the central body, the sun, shows itself capable of a proper luminous act or process. The intensity of the Earth-light, or rather the degree of luminosity which it diffuses, exceeds by a little, in the case of the brightest coloured rays that shoot up to the zenith, the light of the moon in her first quarter. Occasionally, as on the 7th of January, 1831, a printed page can be read without straining the sight. This light-process of the earth, which the Polar regions exhibit almost incessantly, leads us by analogy to the remarkable phenomenon which the planet Venus presents. The portion of this planet which is not illuminated by the sun, glows occasionally with a proper phosphorescent gleam. It is not improbable that the Moon, Jupiter, and Comets, besides the reflected sun-light recognisable by the polariscope, also emit light produced by themselves. Without insisting on the problematical but very common phenomenon of *sheet-lightning*, in which the whole of a deep massy cloud is flickeringly illuminated for several minutes at a time, we find other examples of terrestrial evolutions of light. To this head belong the celebrated *dry-fogs* of 1783 and 1831, which were luminous by night; the steady luminousness of large clouds, perfectly free from all flickering, observed by Rosier and Beccaria; and even the pale, diffused light, as Arago has well observed, which seems to guide us in the open air, in thinly clouded autumn and wintry nights, when there is neither moon nor star in the firmament, nor snow upon the ground. As in the phenomenon of the Polar lights occurring in high northern latitudes, in other words, in electro-magnetic storms floods, of flickering and often parti-coloured light stream through the air, so, in the hotter zones of the earth, between the tropics, are there many square miles of ocean which are similarly light-engendering. Here, however, the magic of the light belongs to the organic forces of nature. Light-foaming flashes of the bursting wave, the wide level glows with lustrous sparks, and every spark is the vital motion of an invisible animal world. So manifold is the source of terrestrial light. And shall we conceive it latent, not yet set free in vapours, as a means of explaining Moser's *pictures*—a discovery in which reality still presents itself to us a vision shrouded in mystery?—*Cosmos.*

TERMS USED IN MECHANICS.

III.—CENTRIFUGAL FORCE.

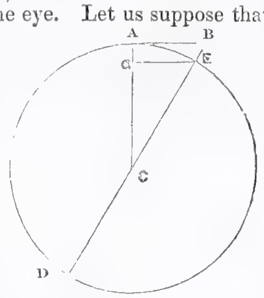
No law in general Mechanics is more certainly established than this—that all motion tends to a straight line; consequently when a body moves in the circumference of a circle, there must necessarily be some force which acts upon and deflects it from the rectilineal direction, and constrains it to remain in the circular orbit; and if the action of that force were suspended, the body would immediately fly off in a straight line, which would be a tangent to the circle at the point in which the body was moving when the force ceased to act. This effort of the body to persevere in a rectilineal path is termed its *centrifugal force.* It may be questioned whether the term *force* is strictly applicable to the mere *passive* resistance which the body offers to the deflecting force; and perhaps it might be advantageously replaced by the term *pressure.* But the appellation has become too thoroughly interwoven with the language of science to allow of any attempt to change it; and the meaning in which the term is used being justly defined, the looseness of the expression can lead to no impropriety of idea, and is therefore of less importance.

The effects of a centrifugal force are familiarly illustrated by many of the operations of the arts, and still more so in some of the sports of early youth. The instance of a stone whirled rapidly round the hand in a sling has often been cited as an illustration with which few are unacquainted. The effort of the stone to fly off in a straight line is the *centrifugal force* developed by the revolving motion; and the reaction of the hand communicated through the strings may be regarded as a *centripetal force* which confines the stone to its circular path. When the string is let slip, the centrifugal force is not counteracted and the stone flies off in a straight line, which is a tangent to the orbit at that point at which the centripetal force ceased to act. It is also a centrifugal force which is the foundation of the boy's amusement in driving a hoop. A hoop at rest, if placed on its edge, would very quickly fall to the ground; but when it is moved forward, a slight inclination towards either side causes the parts to acquire a motion in that direction, those which are uppermost being most affected by it; and the lateral motion, assisted sometimes by the curvature of the surface of the hoop, causes its path to deviate from a rectilineal direction, and instead of moving straight forwards, it moves to that side towards which it began to decline; and in this position its tendency to fall is still further counteracted by the centrifugal force. In the arts the centrifugal drying machine, wherein the cloth is almost literally dried by rapid revolution in a cylinder, without the slightest damage, is a beautiful and direct application of the same principle. The action of the potter's wheel, by the rotation of which the clay under operation swells out regularly by a gentle pressure and gradually recedes from the centre of motion, is not less obvious; and the lengthening of a rod of glass by causing it to revolve in a horizontal plane, and the spreading of a sheet of the same material by the process called *flashing*, are manipulations manifestly depending upon a centrifugal force. It is also on account of the centrifugal force that a given bulk of any material weighs about $\frac{1}{289}$th part less at the equator than at the poles of the earth; and knowing the law under which revolving bodies tend to recede from their centres of motion, we are able to calculate that should it ever come to pass that our globe shall revolve 17 times faster than at present about her axis, and our day thereby become contracted to the short period of 84 minutes, the centrifugal force would at the equator be equal to gravity; and bodies there would have no weight whatever,

and, consequently, a stone thrown upwards from the surface would never return.

The pendulum governor applied to regulate the supply of steam to the steam engine, and also to regulate the sluices of water-wheels, is much too important to pass over a mere enumeration, and will be discussed after we have established the formulæ relating to centrifugul force.

To find a general measure of the force necessary to retain a revolving body in its orbit, and, consequently, of the force with which the body tends to recede from the centre, we must have recourse to a diagram, in which the conditions of the inquiry are represented to the eye. Let us suppose that a body at A, of small dimensions, revolves in the circumference of a circle, whose centre is at C, and that it is continually attracted to that centre by a force represented by F. If AE be an exceedingly small portion of the circular path of the body, and the force, F, remain constant and parallel to itself, whilst that portion of its path is being described, then will the tangential line, AB, denote the space which the body would have traversed in the time of describing the arc AE, if it had moved with its velocity of projection alone from A, and had not been attracted to the centre.



In describing the arc AE of its orbit, it has therefore been constrained from its natural path towards the centre from B to E; consequently if GE be drawn from E parallel to AB, then will AG be the space through which it would have fallen by the attraction towards the centre C *alone*, and had not been projected at all from A. If therefore we put v to represent the velocity which the body would have acquired on this last supposition when it had reached the point G, and W to represent the weight, then

$$F \times AG = \frac{v^2}{2g} \times W$$

But the velocity v which the body would have acquired in falling through the distance AG, by the action of the constant force F, is equal to twice that which would cause it to describe the same distance *uniformly* in the same time. Hence if t be the time of describing AG, we shall have $AG = \frac{v}{2}\,t$, and therefore $\frac{v}{2}$ will be the velocity with which AG would be described uniformly in the time t. If then we represent by V the actual velocity of the body in its path, we shall have

$$\frac{\frac{1}{2}v}{V} = \frac{AG}{AB} \text{ and } v = 2V \cdot \frac{AG}{AB}$$

And by substituting this value of v in the former equation we obtain

$$F \times AG = \frac{2V^2}{g} \cdot \left(\frac{AG}{AB}\right)^2 \times W$$

$$\text{Therefore } F = \frac{2V^2}{g} \cdot \frac{AG}{(AB)^2} \times W$$

But the arc AE being by hypothesis very small, may be considered as equal to its chord, which is a mean proportional between the diameter DE and the versed sine AG;

$$\text{Hence } AG \times DE = AE^2 \;\therefore\; AG = \frac{AE^2}{DE} = \frac{AE^2}{2\,AC}$$

But on the same hypothesis AG = BE; and (Euclid bk. iii. prop. 36)

$$AB^2 = DB\,.\,BE = 2\,AC\,.\,BE; \qquad BE = \frac{AB^2}{2\,AC} = AG$$

consequently putting R = AC to denote the radius of the circle, and making the substitutions indicated in the above value of F, we obtain

$$F = \frac{W.V^2}{g\,R} \quad . \quad . \quad \quad . \quad . \quad . \quad (A)$$

a rule which is very convenient for calculation; and may be thus expressed in words: Multiply the square of the velocity of the body in feet per second by the weight, and divide the product by 32·2 times the radius of the circle of motion, and the quotient will express the centrifugal force in units of the same name as those used to express the weight.

Thus let a body of 10 lbs. revolve in a circle of 2 feet radius, with a velocity of 8·02496 ft. per second: to find the pressure of the centrifugal force,

$$\text{Here } V^2 = (8{\cdot}02496)^2 = 64{\cdot}4 \quad \therefore W.V^2 = 644$$

$$\text{And } gR = 32{\cdot}2 \times 2 = 64{\cdot}4$$

$$\text{Hence } F = \frac{W.V^2}{g\,R} = \frac{644}{64{\cdot}4} = 10 \text{ lbs.}$$

that is, the centrifugal force is just equal to the force of gravity; in other words, to the weight of the body. But suppose we increase the radius of the circle to 4 feet, then

$$F = \frac{644}{128{\cdot}8} = 5 \text{ lbs.}$$

showing that by increasing the radius of the circle without altering the velocity of revolution, we diminish the centrifugal force. If we increase the velocity to 12 ft. a second, and diminish the radius of the circle to 1 foot, then

$$F = \frac{10 \times 12^2}{32{\cdot}2} = \frac{1440}{32{\cdot}2} = 44{\cdot}72 \text{ lbs.}$$

that is, nearly 4½ times the force of gravity.

The relation of the velocity of the body to the circle in which it revolves is expressed by the verbal formula that the centrifugal force is directly as the square of the velocity, and inversely as the radius of the circle in which it revolves.

It may not always be convenient to calculate the velocity in feet per second; and therefore our rule may be put under a different form.

If t = the time in seconds or parts of a second, required by the body to describe the whole circumference of the circle in which it moves, that is, the time of one revolution; and $\pi = 3{\cdot}14159$ be the ratio of the circumference of a circle to the diameter; the circumference will be expressed by $2\,\pi\,R = 6{\cdot}28318\,R$; and the space described (which is the circumference) being as the velocity and the time of description, therefore

$$2\,\pi\,R = V \cdot t \text{ whence } V^2 = \frac{4\,\pi^2\,R^2}{t^2}$$

and substituting this value of V^2 in the equation for F given above, and putting W = 1 we have

$$F = \frac{4\,\pi^2\,R}{g\,t^2} = 1{\cdot}226\,\frac{R}{t^2} \quad . \quad . \quad . \quad (B)$$

which is also a very simple rule, showing that the centrifugal force is directly as the radius of the circle and inversely as the square of the time of revolution.

When great exactness is not required, we may avoid some complexity of calculation by putting

$$1{\cdot}226\,\frac{R}{t^2} = \frac{5\,R}{4\,t^2}$$

Thus supposing a body to move in an orbit, whose radius is 12 feet, and to make one revolution in a second, its centrifugal force would be expressed nearly by

$$\frac{5\,R}{4\,t^2} = \frac{60}{4} = 15 \text{ times its weight,}$$

which, if calculated by the rule as given in its more exact form, will be found to involve an error in excess of ·28 of the unit, the exact number being 14·72 times gravity.

When the centrifugal force is equal to the power of gravity, we have from our first rule approximately

$$V^2 = 32\,R \quad \therefore V = 8\,\sqrt{\tfrac{1}{2}R}$$

that is, the velocity is the same as that which the body would acquire in falling through *half* the radius of its orbit. Hence the centrifugal effort on the tension of a pendulum at the lowest point, after descending through a quadrant, is just double its weight; for in this case $V = 8 \sqrt{R}$ and consequently

$$F = \frac{64\ R}{32\ R} = 2$$

And generally if d express the vertical descent of the pendulum, and $V = 8 \sqrt{d}$, whence $F = \frac{64\ d}{32\ R} = \frac{2\ d}{R}$.

In small arcs the vertical tension may be found by dividing the square of the number of degrees described in each oscillation by 13153. Thus supposing a pendulum to oscillate through 10 degrees, the tension arising from the centrifugal force will, at the lowest point of the arc, be $\frac{100}{13153}$ $=\cdot 007603$ of its weight.

From the preceding rules we might deduce other forms of calculation, but not more simple or easy of application. It may also be demonstrated that when bodies revolve in any other curve than a circle that the centrifugal force is inversely as the chord of curvature at any point of its orbit. This becomes evident from considering that in the case of a body revolving in a circular path, the circle of curvature of the path at any point coincides with it throughout, and the chord of curvature is therefore simply one of the diameters of the circle; consequently for any other curve we shall have $R = \frac{1}{2} C$ where C denotes the chord of curvature: and therefore we have

$$F = 2 \frac{W.V^2}{g\ C} \quad . \quad . \quad . \quad . \quad . \quad . \quad (C)$$

transpose the terms of this equation for V, we have

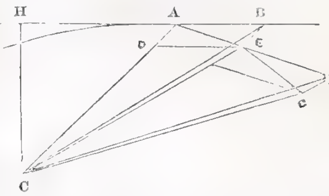
$$V^2 = \tfrac{1}{2} \left(\frac{F\ g}{W}\right) C = 2 \left(\frac{F\ g}{W}\right) \left(\tfrac{1}{4}\ C\right)$$

Now we know that if a body be continually accelerated from a state of rest, if we call the additional velocity communicated to it in each successive second of time, a, and the space through which the velocity V is acquired be called S, then

$$V^2 = 2\ a\ S$$

Now, comparing this with the equation above, we have $a = \frac{F\ g}{W}$ and $S = \frac{1}{4}\ C$; hence it appears that $\frac{F\ g}{W}$ represents the additional velocity per second which would be communicated to a body falling towards the centre of motion if the body fell freely, and the force F remained constant; and since V is the whole velocity which the body on this supposition would acquire, whilst it fell through a space equal to one quarter of the chord of curvature $= \frac{1}{4}\ C$, it thence follows that "the velocity of a body revolving in any point of the curve, is equal to that which it would acquire in falling freely from that point towards the centre of force through one quarter of that chord of curvature (or through one-fourth of the diameter if the orbit be a circle) which passes through the centre of force, if the force which acted upon it at that point in the curve remained constant during its descent. It is in this sense that the velocity of a body moving in any curve about a centre of force is said to be *that due to one-fourth of the chord of curvature*, and to one quarter of the diameter when the path of the body is the circumference of a circle."

A law of great importance in Astronomy, and first discovered by the celebrated Kepler, is, that a right line joining a revolving body and its centre of attraction always describes equal areas in equal times, and the velocity of the body is therefore always inversely as the perpendicular drawn from the centre to the tangent. Thus let A B be a tangent to any curve in which a body is retained by an attracting force directed to C, and let A B represent its velocity at A, or the space which would be described in an instant of time without disturbance; and A D the action of the force C in the same time; then, completing the parallelogram, A E will be the joint result of the two forces. Again, take E F = A E, and E F will now represent its spontaneous motion in another equal instant of time, and by the action of the central force C, it will again describe the diagonal of the parallelogram E G. But triangles on equal bases and on the same parallels are equal (Euclid, bk. i. prop. 36), therefore



$$\triangle ABC = \triangle AEC = \triangle ECF = \triangle ECG;$$

and if these triangles be infinitely diminished and the action of the force C become continual, they will the evanescent increments of the area described by the revolving radius, while the body moves in the curvilinear orbit, and the whole areas described in equal times will therefore be equal. And since the constant area $ABC = AB \times \frac{1}{2}\ CH$, whence $AB = 2\ ABC\ .\ \frac{1}{CH}$; and therefore AB representing the velocity, is always inversely as CH the perpendicular drawn from the centre to the tangent.

CHINA GRASS CLOTH.

The aloe plant exhibits, upon close inspection, a course of long white fibres possessing considerable tenacity. These, when taken from the fleshy part of the leaf, and placed together by themselves, will exhibit a very beautiful clean hemp, corresponding precisely with the material of which the linen called China grass cloth is composed. The aloe grows wild and in great abundance throughout China, and the people of that country have turned it, as they do everything else, to a profitable account. The flax which constitutes the fishing lines known under the name of Indian twist, but which is in reality a Chinese production, is manufactured from the same commodity.

EXPERIMENTS ON THE COMBUSTION OF FUEL, AND THE EVAPORATION OF WATER IN STEAM BOILERS.

BY M. CAVÉ, OF PARIS.

(*Translated and slightly Abridged from M. Armengaud's Publication Industrielle.*)

These elaborate experiments of M. Cavé, which were commenced and brought to a close some years ago, relate entirely to cylindrical boilers with spherical ends, and both with and without return flues and separate water tubes. The extreme care with which they were conducted, coupled with M. Cavé's great experience as an engineer, will, we think, render their results sufficiently trustworthy to be taken as guides in all similar cases.

First Experiment.

The boiler with which the first experiment was tried, together with the furnace to which it is adapted, is represented in the annexed wood-cuts, which are transverse and horizontal sections through the boilers and flues of two different arrangements. The length of this boiler marked A, is 26 feet, and its diameter 3 feet. It is supported in its furnace by a central wall of brickwork, forming two separate bottom flues. The furnace is placed at that end of the boiler marked A in the ground plan, and the flame and heated air proceeding from it, passes along the whole bottom surface of the boiler for a distance of about 3 feet; it then passes along the flue B, proceeding round the further end of the boiler, and returning along the other flue C, as indicated by the arrows. At D, a damper is placed, so as to regulate the draught from this flue to the central one E, which leads directly to the chimney F. In this latter central flue is placed a tube C, of 1 foot in diameter, and about 26 feet in length. Into this tube, the cold feed-water from the force-pump is received, by which

means it is heated before it is pumped into the boiler. This arrangement of flues, &c., has been experimented upon both with grate bars of the ordinary construction, of various dimensions, and with M. Schodet's improved bars, as explained in figs. 3 and 4, which represent the bars shown under the boiler, A, in fig. 1, on a larger scale. These bars are cast very wide; in the present instance they are $8\frac{3}{4}$ in. in width, their surfaces inclining upwards, and forming an obtuse angle along the centre of each bar, so that corresponding recesses

Fig. 1.

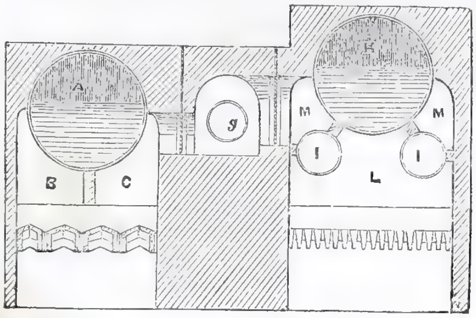
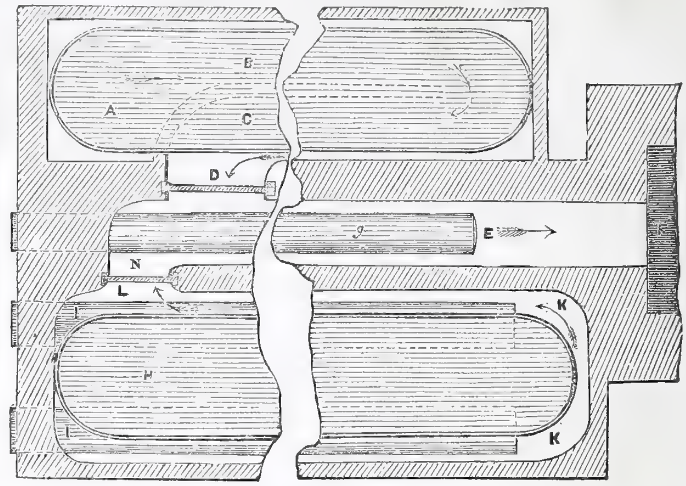


Fig. 2.



are formed by the junction of each pair of bars. To assist the passage of the air through them, a series of oblong narrow apertures are cast along the centre of each bar, of about $\frac{1}{2}$ an inch in width. The ordinary grates used in these experiments, are composed of 21 bars, the total dimensions being about 3 feet 7 inches in length, by 2 feet 6 inches in width, the space allowed between each being $\frac{5}{8}$ths inch, and allowing 2 inches at each end of the bars, where they touch each other, we have for the total area of the passages for the air—

$$21 \times \tfrac{5}{8} \times \overset{\text{ft.}}{2} \text{ “ } \overset{\text{in.}}{2} = \overset{\text{ft.}}{2} \text{ “ } \overset{\text{in.}}{4}$$

The entire surface of the grate being—

$$\overset{\text{ft.}}{3} \text{ “ } \overset{\text{in.}}{7} \times 2 \text{ “ } 6 = \overset{\text{ft.}}{8} \text{ “ } \overset{\text{in.}}{11}$$

Thus, the space for the passage of the air is upwards of $\frac{1}{4}$th of the whole space occupied by the grate.

A further set of experiments were also tried with a grate of the ordinary construction, but of double the area of that given above. This was effected without altering the width of the furnace, by placing another similar set of bars within the furnace, and in a line with those already in use. The total amount of heating surface of this boiler was 133 square feet.

Fig. 3.

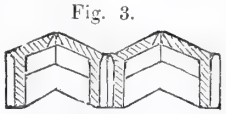
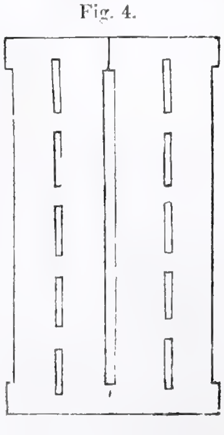


Fig. 4.



By reference to the construction of the bars shown in Figs. 3 and 4, it will be observed, that the amount of space for the passage of the air between them is much less than that given in ordinary grates, amounting, in fact, only to 1-7th of the area of the bars, yet in many instances superior results were obtained from them.

The thickness of the fuel burned upon the improved grates, was from three to four inches, measured from the apex of the bars. It is evident that in fires of this thickness, the air in passing through the burning fuel becomes of much greater value in supporting combustion than with a thinner stratum; but it is also to be observed, that a greater amount of care is requisite in keeping up a regular fire, particularly in boilers of a small size.

The results obtained from this boiler are detailed in the following table of eleven experiments;—

Coal consumed in lbs.	Water Evaporated in Gallons.	Water Evaporated in lbs. per lb. of Coal.	Dimensions, and kind of grate.
1040	824	7·9	Ord. grate, 4 ft 11 in × 3 ft. 7 in.
963	834	8·6	Do. 2 ft 6 in × 3 ft. 7 in.
1040	871	8·4	Do. Do.
930	861	9·3	M. Schodet's improved grate.
1040	792	7·6	Ordinary grate.
864	748	8·7	Improved grate, width reduced to 2 ft. 9 in.
1040	825	7·9	Ordinary grate.
845	675	8·0	Do. width reduced to 2 ft 9 in.
1040	752	7·2	Improved grate, Do, Do.
1016	765	7·5	Do. 3 ft. 7 in. × 2 ft. 6 in.
987	759	7·6	Ordinary grate, do.

Boiler with separate Water Tubes.—In the same figures (1 and 2) is also represented a second boiler H, built in a similar manner into the brickwork, and provided with separate water tubes. The length of this boiler is 27 feet 3 inches, its diameter being the same as in the former instance. The two water tubes I, I, are each 16 inches in diameter, and about 27 feet in length, not including that portion passing through the brickwork at the end of the flue. Each of the tubes communicates with the boiler, by means of two connecting pipes, placed in a line with the brick divisions at J, J, which, together with those at K, K, separate the bottom flue beneath the boiler from the two upper side ones. By this arrangement, the flame from the furnace passes along the bottom flue L, acting upon about three-fourths of the surface of the tubes I, I, as well as upon that portion of the bottom of the boiler included between the two brick divisions. At the back end of the boiler this flue opens into the two upper return flues M, M, along which the flame and heated air is carried and conducted through the damper passage N, into the central flue E, leading to the chimney F.

The total area of heating surface in this boiler was equal to 344 square feet, being more than two and a half times the amount of that in the common boiler, yet with all this advantage, we find that the latter gave the better results. The average of the eleven experiments with the common boiler, gives a result equal

to 8·2 lbs. of water evaporated by 1 lb. of coal, whilst the mean of the two experiments with the boiler with the additional water tubes is only equal to 7·9 lbs., as shown in the annexed table :—

Coal consumed in lbs.	Water evaporated in Gallons.	Water evaporated in lbs. per lb. of Coal	Dimensions, and kind of grate.
1040	784	7·5	Ord. grate 4 ft. 11 in. × 3 ft. 7 in.
1096	906	8·3	Do.

In a subsequent series of experiments with a grate of the ordinary construction, much smaller than those used in the preceding trials, a result equal to 8·4 lbs of water evaporated by 1 lb. of coal was obtained from the first boiler, and 7·5 lbs from the second.

It has been remarked by many experimenters, that boilers provided with very great lengths of flues, which render it necessary that the flame and heated air should make a number of turns, are not so economical in the production of steam as those in which the flame takes a more direct path : in fact, that in many instances the boiler was positively cooled by the passage of the gases along the latter portion of the flues.

However, in the examples now before us, this objection does not seem to obtain, as for instance in the case of the boiler A, the heated air makes only two turns previous to its arrival in the chimney, and there is no reason to suppose that the cooling in the flues of the boiler is at all considerable, as the temperature at the foot of the chimney is much greater than that of the boiler itself.

In accounting, therefore, for the feeble evaporative power of the latter boiler, it is more rational to suppose that the separate water tubes do not produce so much steam as their great amount of heating surface, together with their position in the flue, would lead us to expect. Being quite full of water, it becomes a question whether water is as easily evaporated under these circumstances as with a given amount of steam room, or whether the area of the communicating tubes (being at the same time full of water) is sufficient to give a free escape for the steam to the upper portion of the boiler.

Under all the circumstances of the case, it would appear probable that the disengagement of the steam from the water is more difficult, and that the latter becomes surrounded with a stratum of steam without undergoing evaporation.

This question is undoubtedly deserving of a more minute examination, and we believe M. Cavé intends to enter upon a separate series of experiments to elucidate it.

In continuing our examination of M. Cave's experiments, we find from the first table, that the evaporation of water by 1 lb. of coal is equal to 8·6 lbs., in the common boiler, and with an ordinary grate; but when the latter was replaced by a grate, upon M. Schodet's principle, of the same dimensions, we find the quantity of water evaporated is increased to 9·3 lbs., being a difference of 0·7 lb. in favour of the latter. The succeeding experiments also show the superiority of this grate, but its advantages diminish very nearly in proportion to its size. In the two last experiments, we find that by managing the fire in the best possible manner, that the ordinary grates are more economical than the improved ones of M. Schodet, but the probability is, that this may be attributed to the nature of the fuel employed.

Second Experiment.

Ordinary Boiler.—The boiler used in this experiment was of the same dimensions as the one marked A, of figs. 1 and 2, and was set in the brickwork in a similar manner, except that it was not provided with a return flue, the flame and heated air passing immediately under the bottom of the boiler to the chimney. The object of this arrangement being to determine the relative value of different flues, as well as that of various sized grates. The results obtained by this arrangement are detailed in the annexed table ; from which it will be seen, that the mean of two experiments made with the ordinary grate gives 7·1 lbs. as the quantity of water evaporated per lb. of coal :—

Coal consumed in lbs.	Water Evaporated in Gallons.	Water Evaporated in lbs. per lb. of Coal.	Dimensions, and kind of grate.
1537	1029	6·7	Ordinary grate 2 ft 6 in × 3 ft. 7in.
1742	1318	7·5	Do.

Boiler with separate Water Tubes.—A second boiler, of smaller dimensions, was set in brickwork, parallel with the one just described, and provided with two water tubes, as shown in fig. 1. Its length was 19 ft. 3 in., and its diameter 2 ft. 7 in., the water tubes being 19 ft. 3 in. in length, and 16 inches in diameter. The whole bottom surface of the boiler, as well as the tubes, was completely exposed to the heat, and the flame, &c., passed off immediately to the chimney as before. The total amount of surface exposed to the heat was 228 square feet, the capacity of the boiler being equal to 248 gallons, of which 165 were filled with water, the remainder being appropriated for steam room.

Coal consumed in lbs.	Water Evaporated in Gallons.	Water Evaporated in lbs. per lb. of Coal,	Dimensions, and kind of grate.
1500	1267	8·4	Ord. grate 3 ft 7 in. × 4 ft 11 in.
1269	950	7·4	Do. 2 ft 6 in. × 3 ft 7 in.

These experiments serve to show that with the present arrangement, the boiler with the additional tubes possesses a much higher evaporative power than that which is unprovided with them, whether with the large or the small grates; and also from the nature of the experiments that this advantage is not the result of the additional heating surface, gained by the use of the tubes, but that of the change in the arrangement of the flues.

Third Experiment.

The boilers used in the last trials were re-arranged in the same manner as in the first experiment, with the difference that the passage from the return flue in the ordinary boiler into the central one containing the heating tube, was removed about three feet further from the furnaces. The results of these last experiments are again favourable to boilers of the ordinary construction, without additional water tubes, to the extent of nearly 1 lb. of water evaporated per lb. of coal.

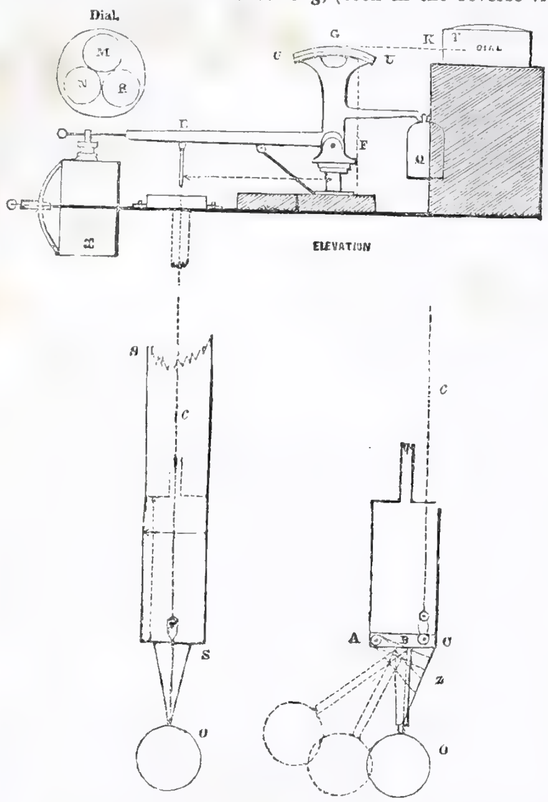
Ordinary Boiler.

Coal consumed in lbs.	Water Evaporated in Gallons.	Water Evaporated in lbs. per lb. of Coal.	Description, and kind of Grate.	
1742	1452	8·3	4 ft. 11 in. × 3 ft. 7 in.	
1742	1399	8·0	Do.	Do.
Boiler with separate Water Tubes.				
1742	1372	7·8	Do.	Do.
1742	1293	7·4	Do.	Do.

M. CLEMENT'S NAUTICAL INVENTIONS.

These inventions are represented by the four nautical instruments, known as the Sillomètre, Sub-Marine Thermometer, Steam Thermometer, and Derivomètre,*—all of which have for some time been in use in the French navy, and the trials which have been made of them on board H. M. steam-vessels, *Lightning* and *Blazer*, show that they are deserving of the same attention in this country.

The Sillomètre.—This, as the name† implies, is an instrument for measuring the rate of a ship's sailing, and might be called in English, the "Marine Speed-Gauge." The drawings subjoined give a general idea of its construction and mode of action; *o* is a copper ball, about five inches diameter, suspended under the ship's bottom, nearly amidships, from the middle of a bent lever A C about five inches long, (seen in the reverse view



on the right). One end of this lever has its fulcrum A attached to the lower end of a metal rod, which passes vertically through a copper tube S S which passes from the deck through the bottom of the ship near the keel; at the other end of the lever is attached a chain *c*, which leads upward, and acts upon a second horizontal lever E F, on deck. This second lever gives motion by means of a spring to an index, and thus marks on a dial T, the action of the lower one upon it—that is, the speed of the vessel expressed in knots and tenths of a knot.

The lever on deck is a bent one, having its fulcrum at F: its arm F G terminates in a circular part U U, over which a fine band passes to work the indicating mechanism, and which by this means is always retained in a horizontal position. The apparatus is balanced by the compensation-weight Q; at the other end is the oil-box *x*.

This is the whole apparatus of the simple sillomètre for measuring the speed of the vessel through the water. It will readily appear that as the vessel advances in the water, the fluid acts upon the ball, which owing to its form always presents the same area to its action, and thereby depressing the forepart of the lever A C, which by the chain *c* communicates with the index upon deck. The scale of knots upon the dial was determined by numerous experiments by the inventor.

The compound sillomètre consists of the same mechanism with this addition, that the power which moves the index is applied also to a timekeeper, and accelerates its movements in proportion to the intensity of the moving power. A second timekeeper is placed by the side of the first, in order to show how much the former gains upon the latter: an acceleration of six seconds is equal to a mile sailed, and knowing this, the whole distance run can be easily computed. This compound instrument is obviously superior to the simple one; but its accuracy depends upon the regular going of two timekeepers, a result which it is somewhat difficult to obtain at sea.

Dial.

The Sub-Marine Thermometer.—This is a very delicate instrument composed of a riband formed of two metals of unequal contraction and expansion as platinum and silver, and rolled into a helix A round an axis B, which turns as the temperature of the water varies. This motion is immediately communicated by a train of wheels to two pointers on a graduated dial on deck, and may be read off easily to hundredths of a degree. The whole of the apparatus is enclosed in a metal tube which passes through the bottom well aft in the run of the ship. The helix or thermometer is therefore always at a certain depth in the water, say ten feet below the surface, and shows instantly every change in its temperature.

The instrument may reasonably be expected to be of the utmost importance to the mariner, by warning him of his approach to shoals, icebergs, rocks, and land, the shallow water being always colder than in the deep sea.*

The Steam Thermometer.—This instrument is intended to point out the temperature, and consequently the pressure, of steam in the boilers. It is likewise composed of a riband of two sensitive metals of unequal expansibility, turned in a spiral form. One end is fixed to the tube in which it is contained; and the other is connected with a spindle bearing the pointers which indicate the temperature of the steam, on a dial on deck, in degrees and tenths of a degree. The instrument is connected by a small pipe with the boiler or steam-chest, through which the steam reaches the spiral, which instantly coils or uncoils with any variation of temperature, and thereby shows upon the dial any change in the tension of the steam in the boiler.

The Derivomètre.—This is an instrument somewhat on the principle of the Sillomètre, and intended to measure the drift of a ship. This is done by a vane placed on the keel, and connected by a rod with a dial on deck. The vane, of course, takes the opposite position to the drift of the vessel.

The following table, extracted from Captain Washington's report to the Board of Admiralty of the performance of three of these instruments, fitted into H. M. steam-vessel *Blazer*, conveys a very favourable idea of the value of M. Clement's inventions to the navigator. The table consists of observations made every 15 minutes, during a run of 9¼ hours, from the Nore to sea:—

* M. Clement is also the inventor of an instrument, which he has named the Internal and External Thermometer. It is a highly sensitive thermometer, so placed against the wall of an observatory or house, as to show the temperature of the air within and without, by two pointers upon the face of the same dial. Her Majesty, we are informed, has ordered such an instrument to be placed in one of the apartments of Buckingham Palace.

† The name is composed of the two French words *sillage*, headway, and *mètre*, measure.

* "Water is much colder over shoals than it is in the open sea, and much colder over large than over small shoals. Again water over shoals near the coast is warmer than it is over those at a distance from it, but still colder than the water of the open sea. It is also colder over shoals in immediate proximity to the coast, than over those which are separated by a deep channel.

"These results are not applicable to water inside of capes and in rivers; less agitated, more exposed to the action of the sun, and in intimate communication with the land, it is hotter or colder than that out of soundings according to the season of the year and the temperature (and clearness) of the atmosphere."—*Le Guide du Navigateur dans l'Océan Atlantique.*

Time.	Rate of Going.		Steam Thermometer.		Sub-marine Thermometer.		Depth water.	Temp. air.	Remarks, Tuesday, April 4, 1843.
A.M. h. m.	Sillom.	Log	Centi. °	Fahr. °	Cent. °	Fahr. °	Fath-oms.	°	
									At anchor at the Nore.—Moderate breezes and fine, wind W.S.W. 3; barometer 29·50. Temperature of water, at ¼ ebb, at 10 feet deep by Newman's standard thermometer 46° Fahr.
5 30	0	0			7·6	45·7		47	M. Clement's sub-marine thermometer 45·9 "
5 45	6·4		108·5	227·3	7·4	45·3			At 5h. 30m. weighed anchor. Tried the steam thermometer at each 1 lb. pressure, as shown by the steam gauge, and found it to agree nearly, the difference being reduced to 0·8 cent.
6 0	6·2	6.6	108·8	227·8	7·7	45·9	9	47	At 6h. 5m. Mouse light vessel N.N.E. ½ a mile. Put Massey's Log overboard, steered E.S.E.
6 15	6·4		108·7	227·7	7·3	45·1	6		
6 30	6·2	6·6	108·2	226·8	7·2	45·0	6½	47½	
6 45	5·6		108·0	227·1	7·3	45·1	4¼		Running through the Queen's Channel.
7 0	6·0		107·6	225·7	7·67	45·8	3	47	
7 15	6·5		107·3	225·1	8·3	46·9	5		N.E. Margate sand buoy S.E. ½ S. Hook buoy W.b.S. On approaching this deep hole, the thermometer suddenly rose 1° centigrade, or 1·8 Fahr.
7 30	6·4		107·7	225·4	8·3	46·9	10½	47	
7 45	6·0		108·0	227·1	8·05	46·5	20		
8 0	6·2		108·5	227·3	7·7	45·9	5	47	At 8h. 20m. passed Margate East Spit buoy.
8 15	6·0		108·2	226·8	7·65	45·8	5		Moderate breezes and fine, wind S.S.W. 3, barometer 29·48 at Elbow buoy.
8 30	6·3		108·0	227·1	7·75	45·9	7½	48	
8 45	6·0		108·5	227·3	7·8	46·0	7¼		At 9h. 40m. at North Sand Head light vessel. Tested the steam thermometer again.
9 0	5·8		107·2	225·0	7·2	45·0	6	49	
									Distance run by Massey's Log . . . . 23·1
									" Common do. . . . . . . 24·0
									" Sillomètre . . . . 21·7
9 15	6·0		108·1	226·6	7·4	45·3	7¼		At 10h. variations of speed as shown by sillometre while the log line was running out . . . . 6·2
9 30	6·2	7·0	108·6	227·5	7·3	45·1	10	49	
9 45	6·2		107·6	225·7	7·45	45·4	11		6·3
									6·4
10 0	6·2	7·1	108·7	227·7	7·3	45·1	12½	49	6·3
10 15	6·4		108·1	226·6	7·1	44·8	16½		
10 30	5·9		109·5	229·1	7·2	45·0	21	49½	Speed by log 7·1 . . . . Mean 6·3
10 45	6·0		110·0	230·0	7·3	45·1	29		
11 0	4·5		110·0	230·0	7·4	45·3	25	50	Order, "Ease her," sillomètre fell to 4½. Steam thermometer rose to 230 Fahr.
11 15	5·0		109·3	228·8	7·3	45·1	24		
11 30	4·4				7·5	45·5	20	50½	From a depth of 30 fathoms crossed the Fall's Bank in 7 fathoms, and stood on again to 25 fathoms; the sub-marine thermometer showed no change.
11 45	5·0				7·6	45·7	9		
Noon.	6·1		108·8	227·8	7·4	45·3	15	51	
15	6·3				7·6	45·7	18		
30	6·6		109·1	228·5	7·7	45·9	20	51½	
45	3·0		109·6	229·1	7·8	46·0	23		Order, "stop her," sillomètre fell from 4·2, to 3·4, 3·0, 2·4, 1·6, 1·0, 0·0. Tried the temperature of the water by Cary's standard thermometer, by Newman's standard, and by Jones' self-register-
1 0	1·0		110·0	230·0	7·8	46·0	22	52	
1 45	0·0		109·2	228·6	7·8	46·0	21		

ing thermometer. All agreed with M. Clement's sub-marine thermometer showing 46° Fahr. Blew off the steam, stopping at each 1 lb. pressure, when we found the temperature, as shown by the steam thermometer, to agree with the elasticity of the steam, as indicated by the steam gauge nearly, the difference being only 0·6 Cent.

Captain Washington sums up his reports with the following remarks :—

" It will be seen from the above observations that the sillomètre showed every variation in the speed of the vessel ; even the alteration caused by a single spoke of the helm was perceptible, and putting the helm hard over caused the ship to lose half her way almost immediately ; as the dial of the instrument is placed on deck, and the index or pointer very conspicuous, the officer of the watch without any trouble may observe it at every turn he takes on the quarterdeck ; and it is obvious that none but the most inattentive person can fail to have a much more correct knowledge of the rate of the vessel's going than he can from heaving the common log once or twice an hour. The Sillomètre will also enable an officer easily to ascertain the best trim of a vessel ; the difference caused by shaking out a reef or by making or shortening sail ; and in a fleet would enable a ship to keep her station by night or by day with great steadiness ; and lastly, it impresses very strongly on the observer the absolute necessity of good steering and giving very little helm when in chase or on a trial of sailing, or at any other time when speed is of importance.

" *The Steam Thermometer* has also a dial placed on deck, so that the officer of the watch can tell at any moment whether there is a sufficiency of steam, or the contrary, and can thus check the wasteful expenditure of coal ; it would point out to the possible, but highly improbable occurrence of no water in the boilers, or an undue increase of the temperature of steam from any other cause. Its chief value, however, would be shown in a high-pressure engine, when it would give immediate warning of any approach to such a degree of temperature or pressure as might be dangerous.

" *The Sub-marine Thermometer* remains constantly at a depth of about ten feet below the surface of the water ; and, owing to its being formed of platina and silver, is extremely sensitive ; and thus every change in the temperature of the sea will be shown at once on the dial on deck.

" As in the Atlantic Ocean and in other deep seas the deep water is said to be warmer than the shallow, it probably would there show, by mere inspection, the approach to shoals, rocks, or land, and serve as an excellent warning. At this season of the year, however, in the shallow waters of the North Sea we observed no such effect ; on the contrary, the temperature of the water gradually decreased from 50° Fahr., at Woolwich, to 44½ at about twenty miles to the eastward of the North Foreland, and as gradually increased on our return to the same point.

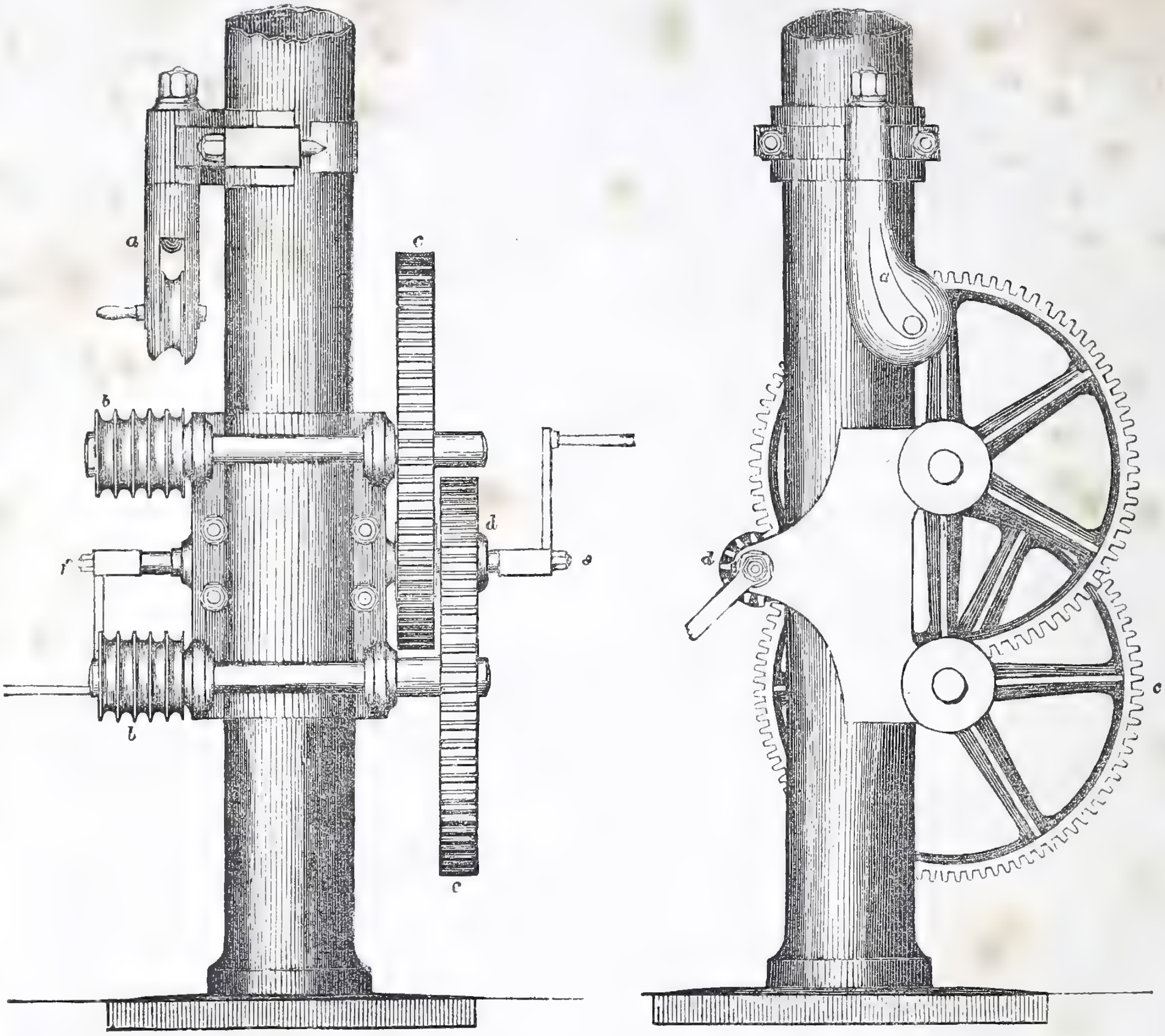
" Possibly as the summer advances this may be different, and in order to discover when the change of temperature takes place, I have directed the instrument to be registered every two hours, night and day. As the Thermometer is highly sensitive and may be read off with ease to hundredths of a degree, and agrees perfectly with the best mercurial thermometers, it may possibly furnish some novel results of value to the philosopher as well as to the navigator, since I am not aware of the existence of any continued series of observations on the temperature of the sea at all seasons of the year."

We have only to add that M. Clement has obtained patents for these different inventions, both in France and in this country.

PILLAR CRANE.

BY SHARP, STEWART, AND CO., MANCHESTER.

This crane is usually fixed to the pillars of workshops and other buildings, where power is occasionally required for raising and shifting heavy bodies. It is so constructed that a tackle rope may be brought to it from any direction; and being passed through the revolving sheave-frame, *a*, the line of direction is so changed as to lead the rope to the two grooved barrels, *b b*. Being passed round these barrels as often as may be considered



necessary, the end of the rope is gathered in as it comes, while the machine is in operation. Motion is given to the two barrels, *b b*, by means of the two spur wheels, *c c*, which both gear into a double-breadth pinion, *d*, keyed upon the crank-handle shaft, *f*. The axis of the sheave-frame, *a*, is so adjusted as to be in a line with the centre of the tackle rope, while passing round the first groove in the barrels, *b b*.

IMPROVED DOUBLE CHURN.

PATENTED IN FRANCE BY M. RENNES.

Figs. 1 and 2 represent a double churn, that is to say, an apparatus for making butter, constructed on the principle of those which have been in use in this country for a very long period, and which are composed, as is well known, of a simple piston worked with the hand, from which it receives an upward and downward movement in a kind of cask or conical barrel containing the cream.

The principal improvement in the churn invented by M. Rennes consists in the mechanism for moving the piston-rods, T. It will be observed from the annexed figures, that this mechanism is composed of a grooved pulley, A, which turns freely round a fixed axis, and receives on its outer circumference the cords, *c*, which are fastened at one end to points in the periphery of the pulley, and fixed by their other extremity to the vertical rods, T, terminating in the pistons, P.

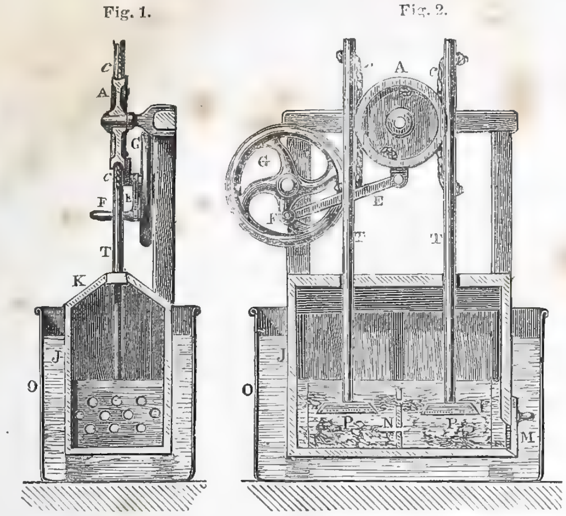
Now, in one piece with the disc, A, or in rigid connection with it, is an iron gudgeon, to which is attached the flat connecting-rod, E, keyed at its extremity to the fly-wheel, G, by the bolt, F. This bolt is prolonged outwards to form a handle or winch, by means of which the fly-wheel is turned, and thus the connecting-rod put in motion.

As the distance from the centre of the pulley to the gudgeon is greater than the radius of the winch-handle, it is evident that, although the bolt, F, describe an entire revolution in the movement of rotation impressed upon it, the gudgeon will simply describe an arc of a circle, the range or chord of which will be equal to double the radius of the handle; and since the gudgeon is solid with the pulley, A, the latter will only receive an alternative circular movement.

In this movement the points of attachment of the cords, *c*, necessarily also describe similar arcs of a circle, and consequently force the rods, T, to which they are likewise attached, to rise and descend alternately.

As these rods are guided in their movement by passing through the upper cross-piece which forms the top of the box

Fig. 1. Fig. 2.



or cask, J, they work, as well as their pistons, in a straight line; and being diametrically opposite in reference to the centre of the pulley, it follows that the one descends while the other rises, and *vice versâ*.

In applying this ingenious method of converting a circular into a rectilinear movement to an apparatus for making butter, the inventor was led to modify and improve the apparatus in other respects. Thus the box or barrel, J, containing the cream, is so contrived as to allow the ingredients to be put in or taken out with great facility. At the top, on one side, is a lid, K, either attached by a hinge, or simply fitted on the box, to be removed when necessary.

In like manner, at the lower part is an opening, which is closed by a slide-valve, M, and which, when the valve is opened, allows the escape of the buttermilk after the operation is finished. A vertical partition, N, pierced with holes, separates the churn into two compartments, in each of which works one of the pistons, P.

When necessary, the box or churn, J, may be placed in a tub or other vessel, O, of wood or of metal, which may be filled with warm water in winter, to accelerate the operation; or, in place of hot water, one might, in certain cases, apply steam.

Thus the improvements introduced by M. Rennes into churns or apparatus for making butter, comprise not only the particular arrangement of the mechanism for moving the pistons, but likewise modifications in the construction of the box or churn, properly so called; and, in particular, the addition of lids and valves to facilitate the putting in and taking out of the materials, without requiring to take the apparatus to pieces; and lastly, the application of heating by a steam or water-bath, to accelerate the operation in cold weather.

THEORY AND PRACTICE OF NAVIGATION.

CHAPTER II.

I.—PLANE SAILING.

Plane Sailing is the method of navigating a ship upon the supposition that the earth is an extended plane. In this sailing, therefore, the meridians are considered as being all parallel to each other, and the parallels of latitude straight lines, at right angles to the meridians; the length of a degree on the equator, meridian, and parallels of latitude as everywhere equal.

Four things are principally concerned in this sailing, namely, the Course, Distance, Difference of Latitude, and Departure.

The Course is the angle contained between the meridian of the place sailed from and the ship's track or path, and is expressed in degrees or points of the compass. Thus, when a ship sails in a north-east direction, we say her course is 4 points, or 45°.

The Distance is the number of miles a ship has sailed on a direct course in a given time.

The Difference of Latitude is the distance which a ship has made north or south of the place sailed from, and is reckoned on a meridian.

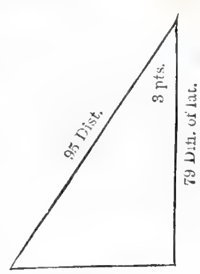
The Departure is the distance a ship has made from the place sailed from, and is reckoned on a parallel of latitude. It is east or west, according as the course is in the eastern or western hemisphere.

From the above it is plain, that if a ship sail due north or south, she sails on a meridian, and makes no departure, her distance and difference of latitude being the same; but if a ship sail due east or west, she sails on a parallel of latitude, and makes no difference of latitude, her departure and distance being the same; but when a ship sails in any other direction, she makes both difference of latitude and of departure: and these, with the distance, form a right-angled triangle, the hypothenuse of which is the distance sailed, the perpendicular is the difference of latitude, the base the departure; the angle opposite the base is the course, and the angle opposite the perpendicular the complement of the course. Hence, any two of these parts being given, the rest may be found by Plane Trigonometry.

In a right-angled triangle, if the base be made radius, the perpendicular will be the tangent of its opposite angle, and the hypothenuse the secant of the same angle.

If the hypothenuse be made radius, the perpendicular and base will each be the sine of its opposite angle.

If the perpendicular be made radius, the base will be the tangent of its opposite angle, and the hypothenuse the secant of the same angle.



The Course and Distance given, to find the Difference of Latitude and Departure.

Example.—A ship from Bombay, in latitude 18° 57′ N., sailed 95 miles SW. by S., 3 points of the compass. What is her departure, difference of latitude, and latitude come to?

To find the Departure.

For the method of taking out the logarithms, see the examples in Chapter I.

As radius, - - - - - - -	10·00000
Is to sine of 3 points, - - - - - -	9·74473
So is distance 95, - - - - - -	1·97772
	11·72245
	10·00000
To the departure, 52·8, - - - - -	1·72245

For the Difference of Latitude.

As radius, - - - - - - -	10·00000
Is to cosine of 3 points, - - - - -	9·91984
So is distance 95, - - - - - -	1·97772
	11·89756
	10·00000
To difference of latitude 79, - - - -	1·89756

To find the Latitude come to.

Latitude left, - - - - - -	18° 57′ N.
Difference of latitude $\frac{79}{60}$, - - - -	1° 19′ S.
Latitude come to, - - - - -	17° 38′ N.

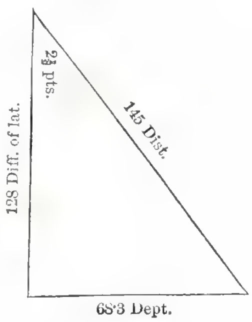
Various scales have been invented to facilitate the solutions of questions in navigation. As the Gunter's Scale is generally understood, we will give a short description of Cameron's Mathematical and Nautical Slide Rule:—

" This instrument is made of good boxwood or ivory, has a joint in the middle, and is 24 inches long when opened out. One side of the rule is marked with inches and a drawing scale, which answers every purpose of a common two-foot rule. On the reverse side of the rule, the rods are marked B, C, and F; each has a line of equal parts, and a mathematical line, called sines, marked S. This line on the rod, C, is divided on the inner edge; the edge of the rod, C, is the line to cut the rod, F; the divisions on the rod, F, are marked on its edges. One-fourth of the joint is divided into 90°, each division representing 2°; the other into 8 points of the compass."

A diagram of the rule, and a more detailed description of its practical use, will be given in the next chapter.

Solution by Cameron's Mathematical Rule.

Set the rod, C, to 3 points of the compass, on the quadrant, A, then move the rod, F, till it cuts 95 on the rod, C, and 79, the difference of latitude, will be given on the rod, B, and 52·8 will be given on the rod, F, as the departure.



The Course and Difference of Latitude given, to find the Distance Sailed, and Departure.

Example.—A ship sails SSE.$\frac{1}{2}$E. ($2\frac{1}{2}$ points) from latitude 14° 45′ S., until she finds by observation that she is in latitude 16° 53′ S.; required what distance she has run, and what departure is made good?

Latitude sailed from, - - - -	14° 45′ S.	subtract.
Latitude come to, - - - - -	16° 53′ S.	
Difference of latitude, - - -	2° 8′	
	60	
In miles, - - - - - -	128	

To find the Departure.

As cosine of course, $2\frac{1}{2}$ points, - - -	9·94546
Is to sine of course, $2\frac{1}{2}$ " - - -	9·67326
So is difference of latitude 128, - - -	2·10721
	11·78047
	9·94546
To the departure, 68·3, - - - -	1·83501

To find the Distance.

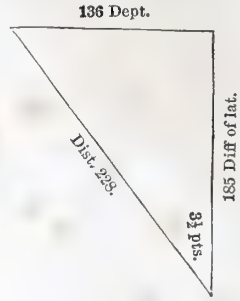
As cosine of course, $2\frac{1}{2}$ points, - - -	9·94546
Is to radius, - - - - - - -	10·00000
So is difference of latitude 128, - - -	2·10721
	12·10721
	9·94546
To the distance, 145, - - - - -	2·16175

Solution by the Mathematical Rule.

If the numbers in any question exceed those on the rule, it is necessary to reduce them in any convenient proportion, and multiply the results in the same proportion. In the present instance, the numbers are reduced to one-fourth.

Set the rod, C, to $2\frac{1}{2}$ points of the compass (SSE. $\frac{1}{2}$E.), on the quadrant, A, then move the rod, F, till it cuts 32 on B ($\frac{1}{4}$ difference of latitude); and 17 on F (the departure) will cut 36·3 on C, the distance.

$32 \times 4 = 128$ difference of latitude.
$17 \times 4 = 68$ departure.
$36{\cdot}3 \times 4 = 145$ distance.



The Course and Departure given, to find the Difference of Latitude and Distance.

Example. — A ship from Port Louis, in the Isle of France, in latitude 20° 10′ S., sailed NW. $\frac{1}{4}$N., $3\frac{1}{4}$ points, until she made 136 miles of departure. What is the distance sailed, and latitude come to?

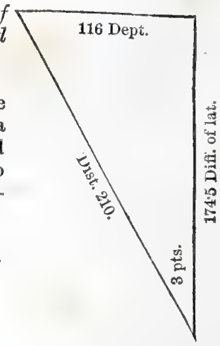
Latitude of Port Louis, -	20° 10′ S.	
Difference of latitude $\frac{183}{60}$ =	3° 3′ N.	subtract.
Latitude come to, - -	17° 7′ S.	

To find the Distance.

As radius, - - - - - -	10·00000
Is to cosecant of course, $3\frac{1}{4}$ points, - -	10·22497
So is the departure, 136, - - - -	2·13354
	12·35851
	10·00000
To the distance, 228, - - - - - -	2·35851

To find Difference of Latitude.

As radius, - - - - - - -	10·00000
Is to cotangent of course, $3\frac{1}{4}$ points, - -	10·12980
So is the departure, 136, - - - -	2·13354
	12·26334
	10·00000
To difference of latitude 183, - - -	2·26334



Given the Distance and Difference of Latitude, to find the Course and Departure.

Example. — A ship, from latitude 28° 29′ N., sailed 210 miles, upon a direct course, between the north and east, and by observation was found to be in latitude 31° 17′ 30″ N. Required the course and departure?

Latitude left, - -	28° 29′ N.	subtract.
Latitude in - -	31° 17′ 30″ N.	
Difference of latitude,	2° 54′ 30″	
	60	
In miles, - - -	174·5	

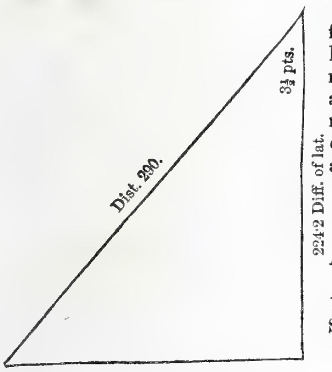
To find the Course.

As the difference of latitude 174·5, - -	2·24204
Is to distance, 210, - - - -	2·32222
So is radius, - - - - - -	10·00000
	12·32222
	2·24204
To secant of course, 3 points, - - -	10·08018

To find the Departure.

As radius, - - - - - - -	10·00000
Is to sine of course, 3 points, - - - -	9·74474
So is the distance, 210, - - - - -	2·32222
	12·06696
	10·00000
To departure, 116·6, - - - - - -	2·06696

Given the Distance and Departure, to find the Course and Difference of Latitude.



184 Dept.

Example.—A ship sailed from Funchal, in Madeira, latitude 32° 38′ N., 290 miles, between the south and west, and made 184 miles of departure. Required the course sailed, and latitude come to?

To find the Course.

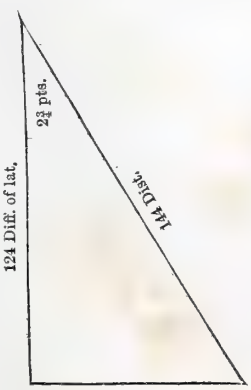
As distance, 290,	2·46240
Is to departure, 184,	2·26482
So is radius, -	10·00000
	12·26482
	2·46240
To sine of course, 3½ points, . .	9·80242

To find Difference of Latitude.

As radius, - - - - - - -	10·00000
Is to cosine of course, 3½ points, - - -	9·88824
So is distance, 290, - - - - - -	2·46240
	12·35064
	10·00000
To difference of latitude 224·2, - -	= 2·35064

Latitude left, - - - - - -	32° 38′ N.
Difference of latitude $\frac{224}{60}$, - -	= 3° 44′ S. subtract.
Latitude come to, - - - - -	28° 54′ N.

Given the Difference of Latitude and Departure, to find the Course and Distance.



74 Dep.

Example.—A ship sails from latitude 42° 50′ N., between south and east, till she has made 74 miles of easting, and is then found by observation to be in latitude 40° 46′ N. Required the course and distance made good?

Latitude left, - -	42° 50′ N.
Latitude by observation, - - - -	40° 46′ N. sub.
Difference of latitude,	2° 4′
	60
In miles, - -	124

To find the Course.

As difference of latitude 124, - - -	2·09342
Is to departure, 74, - - - - - -	1·86923
So is radius, - - - - - -	10·00000
	11·86923
	2·09342
To tangent of course, 2¾ points, - - -	9·77581

To find the Distance.

As radius, - - - - -	10·00000
Is to secant of course, 2¾ points, - - -	10·06618
So is difference of latitude 124, - - -	2·09342
	12·15960
	10·00000
To the distance, 144·4, - - -	= 2·15960

TRAVERSE SAILING.

A ship sailing from one port to another is made to form an irregular tract, from the effects of winds and currents. This tract is called a *traverse*, or *compound course.*

The several courses and distances are arranged into a table, and then resolved as a question of plane sailing.

The table is formed of any convenient width and depth, and is divided into seven columns.

In the first, the points of the compass.

In the second, the various courses.

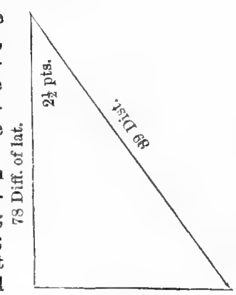
In the third, the distances.

In the fourth and fifth, the differences of latitudes, marked at the top N.S.

In the sixth and seventh, the departures marked at the top, E.W.

The differences of latitude are put in a north or south column, according as the course is northern or southern. Then add the differences of latitude into two sums—the northern into one, and the southern into another, taking their difference for the difference of latitude; and the difference of the sums of easting and westing for the departure from the meridian. When the course of a ship is less than 4 points, the departure is less than the difference of latitude; but the departure is greater than the difference of latitude, if the ship's course be more than 4 points.

Example.—A ship sailed from latitude 41° 18′ N., on the following courses:—SE. by S., 40 miles; SSE., 28 miles; S. by W., 41 miles; NE. ½N., 28 miles.—Find the direct course and distance made good, and the latitude come to?



42·7 Dep.

Points.	Courses.	Distance.	Difference of Latitude.		Departure.	
			N	S.	E.	W.
3	SE. by S.,	40	—	33·3	22·2	—
2	SSE ,.....	28	—	25·9	10·7	—
1	S. by W.,	41	—	40·2	—	8·
3½	NE. ½N.,	28	21·6	—	17·8	—
				99·4	50·7	
				21·6	8	
		Difference of Latitude,.....		77·8	42·7	Departure.

Latitude left, - - - - - - -	41° 18′ N.
Difference of latitude $\frac{78}{60}$, - - - -	= 1° 18′ S.
Latitude come to, - - - - - -	40° N.

To find the Course.

As difference of latitude 78, - - - -	1·89209
Is to departure, 42·7, - - - - - -	1·63043
So is radius, - - - - - -	10·00000
	11·63043
	1·89209
To tangent of course, 28° 42′, - -	= 9·73834

To find the Distance

As radius, - - - - - - - -	10·00000
Is to secant of course, $2\frac{1}{2}$ points, nearly -	10·05693
So is difference of latitude 78, - - -	1·89209
	11·94902
	10·00000
To distance, 89, - - - - - -	= 1·94902

Solution by the Rule.

Set the rod, F, to 78 (difference of latitude) on B; move C to cut 42·7 (departure) on F; and 89, the distance, will be given on C, and 28° 42′ (course) will be given on quadrant, A.

FARRIERY.

CHAPTER IV.

I.—OF THE EYEBALL AND ITS VISUAL STRUCTURE.

THE eyeball is situate within the anterior part of the orbit, or socket fitted for its reception, and is placed nearer to the frontal than the temporal side. It has a degree of prominence peculiar to the individual, and within a certain degree variable at the will of the animal. In front the ball is suspended by the eyelids, laterally and behind; it is slung by seven muscles, and is likewise retained in its position by the optic nerve, together with its blood-vessels, which are enveloped in fat, that forms a sort of cushion for maintaining it in a due state of advancement, and assists in a great degree for retaining its proper position, and securing steadiness to its movements.

The magnitude of the globe or eyeball varies a little in different horses. Its shape is a compound of two spheres of different diameters, united in front by an elliptical line. The smaller sphere protrudes in front of the larger one, and is transparent; the large sphere is opaque, somewhat imperfect in its form; is flattened behind, with its sides prominent. The small sphere, from its resemblance to horn, has been denominated the cornea lucida. The diameter of the eyeball exceeds its axis by about a line and a half.

The *Cornea* (Plate III. fig. 5, *hh*, and Plate IV. fig. 1, *f*) is the only part of the eyeball which is seen in most horses; when the white is visible, it is said to be indicative of bad temper. The pupil, *i*, differs from that of all other animals, being of a transverse elongated oval form, as represented in fig. 6.

We must now refer to Plate IV. fig. 1, that the reader may more perfectly understand the different parts of the eye, and be able to follow the description, as we proceed, of that organ, so important to all animals, and more especially in the horse, where the safety of man is so deeply concerned.

The eye is globular in form, although not perfectly so, being rather composed of parts of two globes; the half of the one, F, smaller and transparent in front, and of the other, G, larger, and the coat of it behind, which is opaque.

According to optical laws, all objects become visible by the rays of light which flow from them into the eye. These rays pass through the pupil, and fall upon the retina, which is a fine expansion of the optic nerve, interwoven like network, in the back, front, or bottom of the eye; and there the rays form a picture of the object, whose apparent bulk depends upon the size of such picture so formed upon the retina. The picture of the object is always inverted upon the retina, which may be termed the mirror of the eye. Suppose an animal to be looking at an arrow, with its barb turned upwards, A B. To make a picture of it on the retina, rays of light must pass from every part of it through the pupil; and as these proceed always in straight lines, it is evident that those emanating from the point of the arrow will flow towards the lower parts of the retina, and those from the pinioned end will incline upwards, while all the intermediate rays between E A, E B, and all others, will follow the same law; it is therefore apparent that a reversed picture will be imprinted on the retina, as at C D. Dr. Paley illustrates this as follows:—"In considering vision as achieved by means of an image formed at the bottom of the eye, we can never reflect, without wonder, on the smallness, yet correctness of the picture, the subtility of the touch, and the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch in diameter, yet the magnitude of objects which it contains are all preserved, are all descriminated in their magnitudes, positions, figures, and colours. A stage-coach passing at its ordinary speed for several minutes, passes in the eye only over one-twelfth of an inch, yet is the change of place in the image distinctly perceived throughout its whole progress."

a a a, The points where the rays, having passed through the cornea, converge by the refracting powers of the lens.

b b b, The rays proceeding from the object to the eye.

c c, The cornea, or horny and transparent portion of the eye, covered by the conjunctiva, uniting different parts together.

The eye is a fine feature in the horse, and a prominent one gives much spirit to his countenance. But if over-prominent, it is a defect, as this great bulging of the cornea produces imperfect vision, by rendering the rays of light too convergent. This defect of vision renders the horse liable to starting and shying upon the road, from any white or uncommon object with which he may meet. In the healthy eye the cornea is quite transparent, and when cloudy is an indication of disease. Consequently, great attention is requisite, in the purchase of a horse, to this point.

d d, The sclerotica (hard firm coat) which covers the whole of the eye, with the exception of that portion occupied by the cornea, composing the white part of the globe, extending from the insertion of the optic nerve to the cornea, and occupying about four-fifths of the entire superficies. It appears to be a prolongation of the covering of the optic nerve; but whether this is the case or not, their union is exceedingly intimate, and the continuity of fibre is the uniting medium. The sclerotic fibres are dense, firm, and elastic; remarkable for their whiteness, and are of the same nature apparently as those that compose ligaments and tendons. They take every variety of direction, and are so strongly interwoven and matted together, that no force the fingers can exert will lacerate it. The chief use of the sclerotica is to give configuration, support, and protection to the abstractedly formless, delicate parts encased within it. It affords attachment to the muscles moving the eyeball.

The sclerotica has the property of absorbing stray rays of light, which might have the effect of dazzling and confusing the horse, and is not found in any part of the field of vision; but, in place of it, is spread a bright green substance, which extends more over the upper than the lower portion, because objects which are most necessary for the animal to see are below the level of the head. By this means he is enabled to see when in the dark. This sea-green colour is best seen in the dusk. The dark pigment producing it is not to be met with in perfectly white horses, or albinos, nor does it exist in those which are cream-coloured; consequently, in such animals the pupil is red, instead of black. In examining their eyes, the covering is not seen, but only the choroid coat itself.

e e, The *crystalline*, or glassy lens, situate behind the pupil, and in front of the vitreous humour; and so named from its resemblance to melted glass. It is a clear gelatinous fluid, much resembling the white of an egg.

f f, The *choroids*, or choroid coat, covered with a black

secretion, or pigment. It is immediately covered by the sclerotica. It extends from around the termination of the optic nerve, by which it is perforated, in intimate contact with the internal surface of the sclerotica, as far forward as the edge of the cornea, where it terminates in the ciliary circle. It is attached to the sclerotica by a very fine cellular web, by intercurrent blood-vessels, and by the ciliary nerves.

g g, The *ciliary circle.*—When that part of the sclerotica in union with the cornea is removed, there is exposed immediately behind the retiring edge of the latter, a whitish circular belt, about two lines in breadth. This is termed the *orbicularis ciliaris*, or ciliary ligament or circle. It forms the line of separation between the choroids and iris.

h h, The *iris* is so denominated from the rainbow-like brilliancy of its appearance, and variety of its tints. It is that part which, in common language, is called the colour of the eye. The iris is perpendicularly extended behind the cornea, after the manner of an internal eyelid, for the purpose of regulating the quantity of light extending to the bottom of the eye. The boundary edge of the iris being fixed within the periphery, just behind the cornea, they both necessarily exhibit the same figure in outline; but, in consequence of the cornea being concave, and the iris flat, an interval is left between them, deepest in the middle; and this is termed the anterior chamber, to distinguish it from a similar space behind the iris, called the posterior chamber. The iris exhibits a perforation, horizontically elliptical, through its middle, which forms the pupil, (Plate III., figs. 5 and 6, *i, i, i,*) or what is vulgarly denominated the sight of the eye. The aperture—for it is nothing more than a hole in the iris—is rather nearer to the inner than the outer, to the upper than the lower, edge of the eyeball; consequently, is attended with a correlative variation in the breadth of the iris at these places. The dimensions of the pupil will vary—and, indeed, so will its form occasionally—according to the condition of the organ, and the quantity of light to which it is exposed. The periphery of the pupil, both above and below, is more or less intruded upon by several little black pendulous bodies, which are the *corpora nigra.*

It is a remarkable fact, that the hue of the iris of the horse corresponds in colour with the hair. Brown horses have brownish eyes; very dark-brown or black horses have eyes of a still darker, dusky-brown shade; bay and chestnut horses have hazel eyes; cream-coloured and white horses are very liable to have wall-eyes, and albinos red.

i i, The *retina* (Plate IV.), or net-like expansion of the optic nerve, spreads over the whole of the choroids, as far as the lens.

j j, The *vitreous*, or glass-like humour, filling the whole of the cavity of the eyeball behind the lens, occupying about three-fourths of the ball of the eye, extending from the back part, or bottom, as far forward as the ciliary ligament.

k, The *aqueous*, or water-like humour. This fills the space between the cornea and the crystalline lens. It is this humour which keeps the cornea in its rounded form.

l, The *conjunctiva*, covering the membrane which lines the eyelids. It is transparent, and transmits the colour of the parts under it.

m m m, The muscles of the eye.

n, The *optic nerve*, or nerve of sight.

II.—STRUCTURE OF THE TEETH AND THEIR DEVELOPMENT.

These instruments are for the abscission and manducation of food. Mastication in the horse is performed in two different ways, viz., by a grinding and by a champing motion. The horse has forty teeth, disposed in pairs—twenty in each jaw. Their form is conoidal or oblong, fixed in the jaws by distinct alveolial processes, of a spongy, bony, open texture, formed in the maxillæ; a portion of the teeth being sunk in the socket, and another portion protruding above it. The former portion is denominated the root, and its pointed extremity the fang; the latter portion is called the body; and the surface which grinds, the face.

The teeth are composed of two hard substances, distinct from each other both in nature and appearance: the one a dense, hard, solid bone, organic in its nature, which is termed the *bony* substance, and the other, which is whiter and harder, called the enamel; this portion is inorganic. The enamel only covers the body of the teeth; the root, or that part situate in the socket, being destitute of it. Upon the face of the teeth the enamel is variously disposed, according to the form of the several individual teeth, from which it sinks more or less deeply into the substance or heart of all the teeth, with the exception of the tusks or tushes. It forms small, funnel-shaped, enamelled cavities, which are termed the *infundibula*, whose mouths are named the *pits*, which are indicated by the black marks upon the surface or faces of the teeth. The different forms of these marks indicate the age of a horse, as they undergo progressive changes annually.

The enamel is merely a covering to defend the teeth, which are essentially formed of bone. Within the bone is a cavity which corresponds in form and dimensions to the tooth itself. This cavity of the tooth contains the pulp enclosed within the membrane of the tooth. These parts are amply provided with blood-vessels and nerves, which pass through the points of the fangs into the vital portions of the teeth.

The teeth are arranged into three classes—first, the *incisors*, or cutting teeth; second, the *canines*, or tusks; third, the *molars*, or grinders.

The horse is provided with twelve *incisor* teeth. These are arranged in parabolic curves in the front of the upper and under jaw-bones, six above and six in the lower jaw. Their form is that of a bent cone, of which the face, or extreme outer surface, is the basis, and the fang—which is inserted in the bone—is the apex. The faces are elliptical; the pits are of the same figure, and single. The fangs are single, and of a conical form. The teeth of the upper jaw are somewhat longer than those of the lower. The general forms of these teeth, but more especially the faces, undergo alterations as age advances; and these changes, which are continued through the whole life of the animal, form the most certain test of the age of the horse. The marks which distinguish the age of the horse, become entirely obliterated at eight years.

The *canine* teeth are four in number, two in each jaw. These are placed in isolated stations, in the interspaces at the sides of the body of the maxilla, between the lateral incisors and the first molars. Their form is that of a double cone, slightly incurved, whose bases are joined together in one body. During growth, the inner side is somewhat concave and fluted. The *cavity* extends without interruption through the entire length of the tooth. The fang is single and perforated. It is not provided with an infundibulum. It is characteristic of the male; in the female, it is either imperfectly developed or entirely wanting.

The *molars* are twenty-four in number. They are sunk in four rows into the sides of the jaws—twelve in the upper and twelve in the lower maxilla; six on each side, equal in magnitude to four or five incisors united together. They are of an oblong quadrangular form, excepting the first and the last teeth, which have occasionally but two each. The lower molars have only two fangs.

In the young horse the teeth are, at certain intervals of age, cast off and replaced by others, and are in consequence distinguished as the *temporary* and *permanent* teeth. The temporary teeth are twenty-four in number, namely, twelve incisors and twelve molars. The temporary incisors differ from the permanent in three particulars—first, in being smaller and whiter; secondly, in having *necks*, or constrictions, where the root joins the body; thirdly, in their fangs being more slender and more acute. The temporary molars differ from the permanent ones—first, in number; secondly, in being individually smaller and whiter; thirdly, in the eminences upon the faces being considerably sharper.

It is the masseter muscle (Plate III., fig. 3, *o*) which, in conjunction with the temporal muscle, acts in closing the jaw, and in effecting its direct cutting or champing motion. The grinding motion, so necessary in reducing the food to a proper condition to enter the stomach, is produced by the pterygoid muscles, which have their origin in the lower jaw-bones, and also assist in shutting the mouth.

There is a space between the branches of the lower jaw, called the *channel*, which is of considerable importance in the choice of an animal, and should be particularly attended to. It may be a little too wide, in which case the face will have a clumsy appearance; but if too narrow, the horse will never be able to bend his head gracefully and freely: he will be always pulling and boring upon the hand, and it is most difficult to rein him in.

The life of a horse may be properly divided into three periods. First, from birth to two and a half years. This is distinguished by the first appearance of the incisor teeth, and by the wearing out of their external cavity. Next is the period indicated by the wearing out of the dental funnel. The table of the incisors during this period contains in its middle the central enamel, and the funnel at first traverses from one side to the other, and becomes in succession triangular, oval, and round. The third period is indicated by the wear of a portion of the tooth next the root. After the central enamel becomes obliterated, the table of the tooth exhibits a coloured point, which disappears before the wear of the funnel is completed, and assumes different shapes, as well as shades of colour; and in very aged horses the root of the tooth is superseded by a small black cavity.

The incisor teeth, at their early stage of growth, resemble a cellular body whose sides are soft and membranous, but speedily become hard and thickened, and are then reflected at the side of the table. Two cavities emanate from this primary dental production, which have a communication with each other, and which, however, are essentially different, the larger being situate next the root. (See Plate VI., fig. 11.) This contains the pulpy substance. The other cavity is open at the side next the table, and forms a reflected funnel. This is quickly transformed into enamel, which is soon surrounded by the bony substance on both its surfaces. The latter incrusts itself in greater quantity on the portion next the root, but never completely fills the funnel, its cavity never being obliterated except through the effects of wear. This funnel, as already observed, is formed by the reflection of the elementary membrane of the tooth, and forms a true partition, which acquires a certain length, and terminates in a rounded blind pouch.

The enamel of the incisors, through wear, is divided into two portions—the exterior or casing enamel, and the other, the interior, which entirely surrounds the funnel. In consequence of the enamel being harder, and offering greater resistance than the bony substance which surrounds it on all sides, the central enamel presents a slight prominence, and assumes several forms, in proportion as the funnel becomes wasted and contracted.

It will be observed, by referring to Plate III., fig. 2, that there exists a considerable space between the incisory teeth, No. 16, as also between the grinders, No. 17, and the tushes, No. 18. The whole of the teeth are seated into sockets consisting of a spongy bony substance, called the alveolar process, which forms the ridge of the maxillary bones. The whole of the teeth are first germinated in the interior of the maxillary bones, and after attaining a certain size, and the exterior table of their sockets having been absorbed, they protrude themselves over the gums. Those which first appear after birth are called the sucking or temporary teeth, and consist of the incisors and three first grinders. The others are formed and make their appearance at a later period, and are termed the permanent teeth, and those which succeed the temporary are called the replacers or horse-teeth.

III.—DENTAL INDICATIONS OF THE AGE OF A HORSE.

All the works of the Framer of the Universe are perfect, and certainly this is strongly manifested by the formation of the grinders of the horse. Like the cutting teeth, they are surrounded on all sides with enamel, except on the top, although their internal structure shows portions of enamel. It is the grinders which are subjected to the greatest degree of friction in the process of mastication, and ample provision is made by Providence for this purpose, as will be explained by the representation of a portion of a grinder. (Plate VI., fig. 9.) The teeth are formed within the cavities of the jaw-bones. In the embryo state, a delicate membranous bag, containing a jelly-like substance, is formed in a cell within the jaw-bone. This substance gradually thickens, becomes long, and assumes the form of a tooth. A hard enamel is then formed outside of this membranous covering. On the first formation, there are, in the upper jaw, five of the membranous bags above described, and filled with jelly-like fluid, and four in the under jaw. This jelly is gradually superseded by a bony substance, which is deposited by small vessels penetrating into it. These vessels are represented by the black streaks shooting through the darker central portions of the figure referred to, around each of which the crystallization of the enamel may be distinctly traced, and forming, as it were, five distinct bones or teeth. The white portions in the figure represent a very hard cement, which unites all these distinct bones into one solid and compact body, thus making but one tooth of the five bags in which it was originally formed. After this an outer coating of strong enamel invests the whole tooth, with the exception of its top, which finishes the formation of the tooth. It will thus be seen that columns of enamel penetrating the whole substance of the tooth, which, with the bony substance and strong cement by which the several layers are united, begin to wear by the constant friction, and leaves the uneven surface observable on the face of the grinders, and that which remains is admirably adapted for performing the grinding of the harder portions of the food.

As already observed, the grinders in the lower jaw are only provided with four of these bags; consequently, they are smaller and narrower, and more regular in their external form, than those of the upper jaw. In both jaws the grinders are placed horizontally; but in the lower one the higher side is within, and gradually shelves outwards, whereas, in the upper jaw, the higher side is without, and shelving inwards; and by this beautiful arrangement, the grinding or triturating motion is performed in the most perfect manner. Each of the grinders is so perceptibly different, that their situation in the jaw can be at once recognized when extracted.

On the birth of the foal, it is provided with the first and second grinders, which are comparatively large in proportion to those by which they are afterwards replaced. The centre nippers or incisory teeth become visible. These are large in comparison to the size of the jaw, and nearly occupy its entire front, as will be seen by Plate V., fig. 1. The third grinders become developed in three weeks or a month, and within six weeks an additional incisory tooth will be formed on each side of the first, both above and below, and speedily become perfect, and the jaw will then have assumed the form represented in fig. 2. The two molars or grinders with which the foal is born, continue in its head until it has reached two and a half years of age, at which period the second set grow and force them out of their sockets. After this period, the grinders need no longer be consulted for the age of a horse, the best test henceforward being the incisory teeth, or nippers, as they are usually denominated. The supplementary molars appear in succession; namely, the first, at about ten or eleven months; the second, at about twenty months; and the third, from four to six years of age.

In consequence of the friction produced by the rubbing of the incisory teeth, they are undergoing nearly a constant change. The front edge is considerably more elevated and sharper than the back or inner edge; the wear first begins there, and in a short time it becomes level with the inner edge; after which, both sides wear together, when the longitudinal cavity gradually becomes narrower, and afterwards of a triangular form, and at a certain period completely disappears. It is succeeded by the small end of the funnel next the root. It is this regular wearing down of the surface of the teeth which obliterates what is termed the mark, and when this is going on, the horse is said to be "losing the mark." (See Plate VI., fig. 1.) This obliteration has frequently taken place by the time the corner teeth have begun to appear. The marks must be distinctly understood to be those on the nippers of the lower jaw, and the age is universally assumed as from the month of May.

When the two edges of the incisory teeth are worn so as to render the outer and inner edges parallel, the upper surface or face of the teeth exhibits two bands of enamel, viz., the exterior, which surrounds the teeth, and is called the *casing* enamel; the other internal, and surrounding the cavity only, which is termed the *central* enamel. (See Plate VI., fig. 11.)

The nippers of the lower jaw always wear sooner than those

of the upper jaw, and are always more regular. This is remarkable, but has never yet been satisfactorily accounted for. Hence the greater difficulty in ascertaining the age of the horse by reference to the nippers of the upper jaw; consequently, they are seldom examined for this purpose. The marks in the central nippers of the lower jaw are always obliterated at about ten months; in the dividers or second incisors, at one year; and from the inner or corner nippers, varying from fifteen months to two years of age.

At this period, the marks of the upper nippers become nearly obliterated, and all the cavities in the whole of these teeth disappear in the upper, as also in the lower, by the time the horse reaches its second year. The crowns, likewise, become insensibly smaller, and their base becomes necked. They likewise become of a yellowish-brown colour, and soon after this they become loose in the gums, and then fall out. From this period, the second age of the horse begins, and the test so well known by the name of the mark takes its rise.

The *mark* in the crown of the nippers is caused by the food producing the hollow pit on its surface, and, by the softer portion being removed, the enamel is bent inwards; and by the gradual wearing down of this by friction. This altering the shape of the blackened pit from time to time, and by its final disappearance, we are for several years enabled to tell the age of the horse.

The tushes (Plate III., fig. 2, No. 18) begin to make their appearance in the course of the third year in many cases, but as these are frequently not visible until the fifth, or even the sixth year, they are no certain criterion as to the age of the animal. They are, however, generally developed in the fourth year. We have represented the appearance of the nippers in the third year at Plate V., fig. 5, from which it will be observed that the central teeth are somewhat larger than the others, and are supplied with two grooves in their convex surface. The mark at this stage is deep, narrow, black, and elongated; and it will be seen that, as these teeth have not obtained their full growth, they are somewhat lower than the other nippers. In the two next teeth, the mark is nearly obliterated, and it is gradually disappearing in the corner teeth. This is the age at which dishonest horse-dealers contrive to cheat the inexperienced. Should they possess a horse which may have been foaled somewhat earlier than usual, say in January, and which may have acquired flesh, and be bulky in appearance, they draw or punch out the central incisory teeth, and this induces the new ones to appear some months earlier than they would have done. By this trick a colt is frequently sold for a year older than he really is, and before he in reality posesses that strength to enable him to withstand heavy work; and, in consequence, his constitution is much impaired by premature labour, and he becomes aged, years before the time he otherwise would have been so.

But to those experienced in horses, this trick will be manifest; because they will examine the general form of the horse, and likewise the forehead, which is always small in the young animal. Besides, the second pair of incisors will still retain the mark, and it will likewise be greatly stronger in the corner teeth, with an enlargement or irregularity, in all probability, about the gums, occasioned by those teeth having been forcibly extracted; and the first and fifth grinders will be too small for the additional years, and the sixth will not yet have appeared. When such an imposition is practised, the perpetrators seldom have recourse to extracting the corresponding teeth in the upper jaw, and an examination of it will easily prove the trick, as the signs will be quite apparent there.

When the horse has attained his third year, he will have the central prominent nippers, with their edges sharp in comparison to the others, all of which will be found in a state of decay, and he will be provided with six grinders in both jaws on each side, and it will be found that the first and sixth of these will be level with the rest, with the sixth protruding. (Plate V., fig. 5.)

At from three and a half to four years, the middle pair of nippers will be nearly perfect, and the second will have been cast, and where they were inserted a vacant space will be apparent. The corner ones will be narrower, and their crowns considerably flattened, with the mark much diminished in size, and indistinct. This is the period at which the second grinders are shed.

At the age of four, the incisory teeth attain their full size, and the sharp edge incidental to the growing teeth will have got considerably blunted. At this stage the mark becomes wider, shorter, and more faint in colour, as in Plate V., fig. 6. By this time the second pair will nearly have attained their full size, bnt still somewhat smaller. The mark will be very deep, extending entirely across the surface. The corner nippers will be a little larger than the inner ones, although somewhat smaller than they were, with the surface flattened, and the mark almost wholly obliterated. The sixth molar or grinder will have been levelled with the others, and the tushes or tusks considerably advanced in growth. But his mouth will not have acquired its full depth, the forehead will still be low, and his legs will appear long in proportion to his bulk.

But it is between four and a half and five years that the last and most important change in the mouth of the horse takes place. The corner nippers are now shed, and the permanent ones, which are to fill their place, begin to appear. The central nippers are now considerably worn down, and the next are beginning to show signs of wear. At this time the tushes are more than half an inch above the gums, and exhibit an external rounded protrusion with a groove on each side.

The animal is called a colt up to the time that the corner incisory teeth are reproduced, and from that period he is called a horse; and from its youth the female is designated a filly, and is now denominated a mare.

At the age of five years, the mouth of a horse is nearly perfect. The corner nippers are fully grown, with the mark on the inside of a lengthened triangular form. (See Plate V., fig. 7.) The remaining incisors are considerably worn at this time, and the tushes very considerably enlarged, with their side grooves almost entirely obliterated, and the tushes exhibiting a nearly regular convex surface. But they are yet concave within, with their edges nearly as sharp as they were six weeks previously. The sixth grinder will have now become complete in height, and the third grinder will be wanting. This criterion is one of the most certain, and if a dishonest dealer has practised deceit by removing it, the force required in extracting it will leave unmistakeable evidence of the fact. The three last grinders and the tushes are never shed.

By the time the horse has reached its sixth year, the mark on the central nippers is completely obliterated, but in the centre of the teeth a slight difference of colour will still be observable. The cement filling the aperture occasioned by the dipping in of the enamel, will exhibit a browner tinge than the other portions of the tooth, and present evident proofs of the edge being surrounded by enamel, and there will still remain a small hollow in the centre, likewise a small depression surrounding this casing of enamel. People who have had little experience in horses are frequently much puzzled by this, as they expect to find the surface of the tooth plain, and presenting a uniform colour; and this irregularity and discoloration puzzles them to account for it. (See Plate V., fig. 8.) The mark in the second nipper is shorter, broader, and more regular in form, while the enamel on the edges of the corner teeth is more regular, and the surface showing evident signs of wear. At this period the tushes acquire their full size, and are rather more than an inch in length, convex outwardly, and slightly concave inwardly, acuminated towards the point, with the apex somewhat curved. The third grinder will have reached its full height, and the surface of the whole be quite level. The mouth of the animal is now in its most perfect condition, but sometimes it will be found to be so six months prior to this time.

It is curious that, while the dentition in the horse requires so many years (considering the fact of his longevity) in arriving at perfection, he seems to suffer but little pain. It is a rare thing, indeed, for the horse to be rendered unserviceable during the growth of his teeth. It sometimes, although rarely, happens that there is a slight swelling and heat in the gums. This will soon be observed from a shyness at taking hard food, and will be speedily removed by the gums being slightly

scarified at the places where the swellings exist. This is another proof of design, for were the horse to suffer as the human being does, he would be useless for work during many months at a time, and, being unable to feed freely, would fall off in his carcase. Dogs suffer considerably during dentition, and in many instances have convulsions, and some even die.

When the horse has attained its seventh year, all the marks on the nippers of the lower jaw will have disappeared, and their surface will be quite level; they likewise change in their form, and become oval, while the cavity is altered into an elongated transverse protrusion of enamel, being the termination of the central enamel or funnel, situate next the root. (Plate V., fig. 9.) After this period, it becomes requisite to have recourse to an examination of the nippers of the upper jaw, to assist in ascertaining the age of the horse. It will be found that, for some years after the marks in the lower jaw have quite disappeared, traces of them will still be observable in the nippers of the upper jaw. This arises from the enamel, which occupies the pit in the centre of the teeth, not being elevated to a level with the general surface; consequently, there is a greater depth to be worn down before it can be obliterated. Besides this, the upper incisors are less liable to wear from friction than those of the lower jaw, as the lower jaw alone moves while in the act of chewing, the upper jaw being motionless and fixed, and only resisting the pressure in mastication.

No aid is afforded by the tushes in ascertaining the age of a horse, from the very uncertain change in their form—their shape is so variable in different animals, being sometimes blunt the first year, and continuing so during life, while in other instances they will continue pointed until the animal is eighteen or twenty years of age. This is in consequence of their not rubbing against each other, as the nippers and grinders do.

After eight years, the age of a horse can be best ascertained from the form of the upper nippers, whose surfaces are transversely oval; that is, from the edge of one tooth to that of the next, on both sides. As the animals become older, they diminish in size, and the width is the first affected, and not the thickness. Soon after this they separate a little from each other, and their surface becomes somewhat rounded, which continues to be the case until the animal has reached its tenth year, when they assume a new character, and become triangular in the same order in which they progressed to the oval and rounded form.

At nine, the centre nippers are rounded, and the next ones begin to assume that form; the remainder of the funnel of these four teeth is round, and quite close to the edge of the teeth, and the septum of the root is also visible.

The nippers will be considerably shortened in their oval form when the horse has reached its tenth year; a mere rudiment of the funnels of the nippers, as well as of the dividers, will be visible, and the remaining portion of the central enamel will be found to touch the inner edge of the table of the tooth. The nippers and dividers will be rounded, and the corner teeth will be of an oval shape. (Plate VI., fig. 2.)

At the age of eleven, the second pair of nippers are quite rounded, and the central enamel of the nippers of the lower jaw is scarcely visible.

At twelve, the corner teeth are rounded, and the central enamel is entirely obliterated; the yellowish band is greater in extent, and occupies the centre of the wearing surface. But the central enamel still remains in the upper jaw. (Plate VI., fig. 3.)

The lower nippers are rounded, and are becoming elongated at the age of thirteen. The central enamel continues in the teeth of the upper jaw, but is getting somewhat rounded, and approaching towards the inner edge. The septum at the root of the dividers is rounded, and is visible in the middle of the table. By this time the tushes get considerably blunted from wear.

At fourteen, the lower nippers exhibit a triangular shape, the dividers become long at the sides, the central enamel of the upper teeth diminishes, but is still visible. The tushes will be found to have considerably diminished since the former year. (Plate VI., fig. 4.)

The nippers are triangular at fifteen, and the dividers are assuming that form; the central enamel of the upper incisors is still apparent. The septum of the roots are rounded in the point on all the tables of the teeth.

At sixteen, the dividers are triangular, and the corner teeth begin to assume that form; the central enamel in the upper nippers will now, in most instances, have quite disappeared, and the nippers will be flattened at their sides. The tushes will be much more worn than on the previous year.

By the time the horse has attained its seventeenth year, the nippers of the lower jaw are completely triangular, with the sides equal in length. (Plate VI., fig. 5.)

The lateral portions of the triangles lengthen in succession at eighteen; first the nippers, then the dividers, and lastly, the corner teeth.

At nineteen, the angles begin to wear off; the central teeth again become oval, but in a contrary direction, namely, from the front inwards, and the nippers of the lower jaw are flattened from one side to the other. This triangular form is not very much developed at first, the edges being slightly rounded, and the three sides are of very unequal length. Afterwards, however, the lateral portions grow longer, while the anterior or outer side seems to diminish, the extremities become angular, and this lengthening shortly afterwards is so great, that at the age of nineteen or twenty the nippers have become quite flattened from one side to the other. This flattening proceeds successively from the nippers to the dividers, and then to the corner teeth, in such a regular way that it enables persons to distinguish the age of the horse up to twenty-two or twenty-three years of age.

At twenty, the dividers are of the shape above described, and at twenty-one all the teeth are of this form.

After the horse has attained this age, the nippers do not acquire any new form or character which will enable us to determine his age. They, however, gradually get more flattened, and converge towards each other, being only in contact at their lateral and anterior edges. They gradually become dried, the gums whiten, and the tables assume a greyish hue, and they are frequently encrusted at their base by a thick coating of tartar. The jaw-bones now gradually become more narrow.

The teeth are continually growing upwards, the bone at the side next the root, while the socket is not sufficiently long; consequently, the pressure of the new portion of the root gives the tooth an outward inclination. These new portions, likewise, being always narrower, the sockets must, of course, contract, in order to secure the teeth in their places. The superior maxillaries become flattened at this period, and the head assumes a lengthened, pointed shape, giving the animal an appearance of being aged. The horizontal direction, owing to the same cause, is always a test of advanced life. However, this direction is not so much developed in some horses as in others, which has not yet been satisfactorily accounted for.

As a horse advances in years, the horizontal direction of the teeth increases, and we have given a fine example of this (Pl. VI., fig. 6), taken from the cranium of a horse seventy-six years of age, called Old Billy, which is preserved in the Manchester Natural History Society's Museum. Both the upper and lower nippers are much lengthened horizontally. The upper surface of the nippers, as well as the dividers, are of a square form, with their inner edges somewhat rounded, and the corner teeth are oblong-oval, or nearly egg-shaped, with the acute end outwards. The tushes are of an obliquely conical shape, and bent backwards, a little blunted at their points, and provided with an elongated, shallow curved groove on their inner sides. The outer margin of the nippers, as also the dividers, is nearly parallel, the corner teeth being only slightly advanced beyond the others. The jaw-bones themselves have not increased in length, the teeth only having advanced forward, so that their surface presents an oblique direction, and are consequently much elongated from back to front, more especially the corner teeth. The tushes, it will be seen, are also large in proportion.

The nippers lie parallel to the axis of the jaw, that is, perpendicular to it; the dividers are somewhat oblique, and the corner teeth still more so, with their roots turning inwards;

and the semicircle formed by the roots of these teeth is much narrower, and occupies less space than that of the free portion.

It is necessary to describe the changes in the shape, length, and general proportions to which the roots of the teeth are subjected as the horse advances in years. When the teeth are emerging from the gums, the root is round, short, and hollow; the internal cavity, the sides of which are exceedingly thin, being only of temporary duration, do not exhibit, as in the external cavity, a kind of funnel, which is peculiar to the latter. It is deeply buried, externally prolonged, surrounds the funnel, and contains a pulpy substance, which, no doubt, is the germ of vitality, and nourishment of the tooth. As the animal increases in years, a progressive diminution of this cavity takes place, commencing at the bottom, and continuing towards the inner margin of the tooth, and is collected from the side next the root. The latter lengthens, continues constantly to grow, and the first portions, instead of being rounded, are at first triangular, and afterwards flattened from side to side, and ultimately, at a period that varies in some horses according to the teeth, the cavity totally disappears; the root is then pointed at its termination, and entirely ceases to grow.

The total length of the temporary nippers varies in length from an inch and a quarter to an inch and three quarters; and the permanent incisors from two inches and a half to three and a quarter. Their shape is not the same throughout, as next to the surface of wear they become flattened from the front to the back, and they narrow towards the margin of the socket, and are at first oval, and afterwards become rounded and somewhat triangular; towards the base of the root, the extremity is flattened from one side to the other. The nippers and dividers exhibit this variation in a greater degree than in the corner teeth. This will be better understood by a reference to the various sections of an incisory tooth or nipper, of about a quarter of an inch apart. On Plate VI., figs. 7, 8, 14, 15, are given five transverse sections of the tooth of a young horse; figs. 7, 8, 14, 15, have the funnel, and section; fig. 15 likewise shows the septum of the root of the tooth.

On Plate V., fig. 11, *a*, is the tooth of a foal, viewed posteriorly or from the inner surface, exhibiting the mouth of the cavity of the funnel of the table.

Fig. 10 shows another tooth of a foal, viewed exteriorly; *a*, the body of the tooth, *b*, the neck, and *c*, the root.

Fig. 16 represents the tooth of a very young foal, in which the casing, or outer enamel, is cut through its whole length, and exhibiting the central enamel, *a*.

Fig. 11 shows an incisor tooth of a horse divided into two parts, its whole length, and shows the external cavity, *a*, and the internal cavity, *b*.

Fig. 13, the incisory tooth of a young horse, cut open in the middle of the anterior surface, leaving the lower portion of the funnel exposed, *a*.

Fig. 10 shows an incisory tooth of a young horse, divided throughout its entire length; *a* is the exterior cavity, and *b* the extremity of the funnel.

BOTANY.

CHAPTER IX.

II.—THE STAMENS.

The two outer whorls of flowers, namely, the Calyx and Corolla, being already considered, we shall proceed to the two inner, which are the Stamens and Pistil. These are, strictly, the sexual organs—the stamens producing a male powder, and the pistil, which forms the germ of the new plant, being impregnated by it. The organs exist in different combinations; in some cases, they are present in the same flower, as in Ricinus communis, Castor-oil tree; in others they are separated on different individuals, as in Cannabis sativa, Hemp; while in others, the flowers are some male, some female, and some mixed, as in Acer, Maple tree. An ordinary condition, then, is that of union; and when both organs are found thus together on the same flower, the plant is known as *hermaphrodite* (chemistry of love). If the sexual organs are separated on different flowers of the same plant, the plant is said to be *monœcious* (μόνος, single, and οἰκίον, habitation); but if separated on different individuals of a plant, the flowers are called staminiferous (*fero*, to bear) or pistiliferous, according to the presence of either organs; and, more generally, the terms employed in reference to the plants themselves are, *unisexual* (*unus*, one, and *sexus*, *a seco*, sex) *diclinous* (δὶς, twice, and κλίνη, bed) or *diœcious* (δὶς, and οικίον). In those cases where distinct flowers occur, both of a male, female, and mixed character, in the same plant, the plants bear the name of *polygamous* (πολὺς, many, and γάμος, nuptials).

There is another topic of common interest to be adverted to in passing. The stamens may be either equal or unequal in number, with the leaves of the calyx and corolla: in the first case, they are called *iso-stemonous* (ἴσος, equal, and στήμων, a stamen), and in the latter, *aniso-stemonous* (ἄνισὸς, unequal). When the stamens exist in more than one row, and collectively amount to twice the number of the sepals and petals, they are called *diplo-stemonous* (διπλους, double); if more than double, *poly-stemonous* (πολὺς, many); but if the number of stamens fall beneath the ratio of that of the outer envelopes, they are *mio-stemonous* (μείων, less). The parts of each of these whorls, in general, successively alternate. The normal position of the first row of stamens is always, therefore, opposite to the sepals, and alternate with the petals; the second and third rows alternate, in like manner, with the first and second. There are exceptions, which occur from the law of abortion; for instance, the single row of stamens in the Primrose is opposite the petals, in consequence of the first row not being developed; and in Silene, or Catchfly, the stamens are double the petals, being 10 to 5, from the former constituting a double row.

The names bestowed by the older botanists upon the stamens, were *Apices* (*apex*, summit), or *Chives* (*cive*, Fr.) Stamen is derived from the Greek, the primitive of which is ἵστημι, to stand; it signifies the thread of the weft, or the warp in the upright loom of the ancients.

It has been formerly hinted, that the receptacle supplies the normal points of insertion to the stamens; and when these points are arranged in verticils, they constitute the androcæum, or male habitation of the plant. But though it is from these points in the axis of the flower, invariably interior of the corolla, that the physiological rise of the stamens takes place, their adhesion with the other organs often supplies an appearance of more superficial insertion; thus, in the Apple-flower, the stamens adhere to the calyx up to a certain point, and for this reason are popularly said to arise from that point. Now, the stamens have been named, according to their relative position, with other parts of fructification. When they originate upon or above the pistil, they are *epigynous* (ἐπὶ and γυνὴ, female), as in Angelica tree; when arising from under the pistil, as in Tulip tree, they are *hypogynous* (ὑπὸ, under); but when inserted into the calyx or corolla, they are *perigynous* (περὶ, around), as in Almond. The terms, thus significant of the relations of the stamina, acquire a new importance in systematic botany, from having furnished the distinctions in the families of plants, according to which the classes and subclasses of the natural system of Jussieu are arranged. Decandolle employs the terms thalami-floræ, calyci-floræ, and corolli-floræ, in their suggestive sense, as the stamens among other parts may have been borne by the thalamus, calyx, or corolla.

Stamens are a modification of leaves,—in fact, a form of concentrated petals; and in double flowers, as Pæony and Dahlia, cultivation causes them to relapse into petals by a gradual but perceptible transition. The petal undergoes a contraction at the upper part first; and the cellular tissue of the leaf condensing into grains, the midrib comes gradually to assume the character of a stem, on which they are suspended. The upper portion of the organ formed in the manner pointed out, is termed the anther, which contains the powdery matter called pollen; this may be sessile or seated closely on the androcæum, as in Mislcto; but if a stalk exist, that is named the filament. See Plate X., fig. 8: *a*, anther; *b*, filament; *c*, pollen.

A few remarks are necessary in explanation of these several structures.

The *Filament* (*filum*, a thread) is the slender body of the stamen, equivalent to the petiole of the leaf. Some plants represent it in little or no degree, and not unfrequently it is flat or broad. In structure and function it resembles the petiole, and is only essential to the stamen as such, as a supporting medium. Its substance is composed of cellular tissue, traversed by spiral vessels, and surrounded with an epidermis. It may be viewed with a reference to base, middle, and top.

The filament may arise out of the androcæum by a simple extension, as in Bell-flowered, when it continues persistent after withering; but if an articulation exists, the piece uniformly falls off after fertilization. Scales and other processes occasionally present themselves as accidents. The common Borage exhibits glandular appendages; and the filaments are then known either as appendiculate or strumose (*struma*, a swelling). From their base upward, the filaments may be either separate, or united into one or more masses. A simple dilatation of the base takes place in German Tamarisk. An adhesion of the lower parts sometimes ensues, so as to cause a tubular form with the terminal points free; and when this adhesion gives rise either to one or more columns, branched with anthers at the upper extremity, it is called *androphore* (ἀνὴρ, male, and φορέω, to bear), as in Egyptian St. John's wort. But irrespective of this particular form, the filaments in many species are arranged into one or more tubes, pervading a greater or less portion of their length, and the Greek word ἀδελφὸς, used for the state of brotherhood or fraternity, is employed to express the set in which the united filaments are combined. When they join in one central bundle or family league, they become *mono-adelphous* (μόνος, single), as in Mallow and Geranium; in two sets, or when only one stamen stands separated from the others in a set, they are *di-adelphous* (δὶς, twice), as in Pea and Fumitory; and above that number, *poly-adelphous* (πολὺς, many), as in Citron, St. Peter's wort, &c.

The middle part of the filament is often continuous throughout; but when bent or jointed, it is geniculate (*genu*, knee). In Pellitory, it is spiral. In respect of form, indeed, the diversity is considerable, being petaloid (πέταλον, petal, and εἶδος, form), or leaf-like, in Indian Arrow-root; subulate, or awl-shaped, in Flowering-rush; and clavate, or club-shaped, in Meadow-rue. Hairs, with movements of rotation in them, are sometimes beautifully developed, as in Spiderwort; and the filament is then said to be bearded, or stupose (*stupa*, tow).

The apex of the stalk is adapted to the load it is intended to fit. The particular contrivance is different in species. Thus, in Garlic, it is toothed.

But the knob-like body which its filament sustains, is the *Anther* (ἀνθηρὸς, blooming), or fertilizing organ of a flower. In the first instance, it makes its appearance as a cellular projection, invariably sessile, and for this reason the filament is always the later part that is developed. In the progress of growth, however, numerous changes come to be effected in the anther; in addition to the production of a filament, where that is proper, it is elaborated among different plants, either free, or in combination with other individual anthers. Stamens uniting by their anthers, are called *syngenesious* (σὺν, and γένεσις, generation), or *syn-antherous*, as in Sheep's Scabious and Violet.

The particulars to be attended to by the reader in the study of this object, comprise its external covering; the cellular matter with which it is filled; the walls which pervade it, forming lobes; the cavities or cases within these; the pollen secreted there; and the manner in which the contents are shed.

1. The external covering consists of a globular row of cells, forming a sort of epidermis. It takes the name of *exo-thecium* (ἔξω, outward, and θηκίον, little repository). The lower part which joins to the filament is called the back, and the part opposite to it is the face. Stomata and projections make their appearance on its surface.

2. The interior of this little ball, in its incipient state, is to be supposed occupied with cellular matter, the whole mass of which is different from the outer covering. Each cell of its tissue, when minutely examined, is found to have diffused through it spiral, annular, or reticulated fibres, which serve to define their outline; and the anterior and posterior cells are analogous to the laminæ of the leaf, in respect of the different structures of its upper and under surfaces. The function of these cells seems to contribute a mucilage for the nourishment of the semen forthwith to be noticed; and it is observed that the absorption of the latter is more or less complete as the other advances to maturity.

3. In its progress, the cellular matter begins to be pervaded by the filament; more generally, however, a fleshy membrane, called the *connective*, is extended from the top of the filament for that purpose, and differs in structure from the spiral vessels which terminate the other. The presence of this agent chambers or cleaves the anther into two or more bag-like masses, the face of which is expressed by a furrow or suture, and the divisions are called septa, partitions or lobes. The connective does not consist of the cover of the lobes, but is merely the membrane that unites them. Occasionally it is of considerable size, as in Bigonia manicata, where it extends entirely across the lobes; but more frequently it encompases only a small portion, as in Mercurialis annua. If an articulation exist at the point of junction with the filament, as in Grasses, the anther is rendered slightly moveable or versatile (*verto*, to turn). When the base of the anther stands upright on the filament, it is *innate* or *erect;* but when the lobes lie on each side of the connective, as in Ranunculus, the anther is *adnate* or *adherent.* The attachment of the filament is at the middle of the connective, in the pendulous anther of Round-leaved Winter-green. When the connective is horizontal, and bears lobes at a distance from each other, it is *distractile* (*dis*, and *traho*, to draw), as in Garden sage. The connective is pointed in Acalypha, conical in Balsam-bearing Humiriad, spurred in Sweet Violet, and a feathered prolongation in Common Rose-bay.

4. As the development approaches completion, a cavity becomes manifest in the interior of each compartment of the anther; and the wall which arches it with a row of fine cells, placed towards each other in contact or in wider degrees of proximity, is called the *endo-thecium* (ἔνδον, inner.) The cavity itself is a loculus or pouch; and the two terms are used in common practice to characterize it. When one cavity only exists, the anther is called *mono-thecal* (μονος, and θηκη), or unilocular (*unus*, one, and *loculus*), as in Bladder-nut. When there are two cavities, it is *bilocular* or *di-thecal* (*bis* and *dis*, twice), as in Stock-gilly-flower. When four cavities are present, either in apposition, as in the Spurgewort, known as Poranthera, or in vertical relation, as in Avocada-pear, the name given is *quadrilocular* or *tetra-thecal* (*quatuor* and τετρος, four). More numerous cavities occur in Patmaworts and Misleto.

5. The loculi we have spoken of are merely hollow cases, filled with a new disposition of cells, called the pollen cells; for within or from them the farina or pollen is produced that effects all vegetable impregnation. The colour of the pollen is often yellow, but also red and blue, with their several modifications of shades, excepting green. It is yellow in Eschscholtzia, red in peach, and purple in poppy. To the unassisted view, pollen presents the appearance of fine dust; but under the microscope, each grain is transformed into a hollow ball, in which floats an oily fluid in particles from the $\frac{1}{30000}$ downwards of an inch in diameter, interspersed with elongated corpuscles somewhat larger, and a granular semifluid matter called the fovilla. In the progress of development, the grain becomes divided into four cells or parts, each forming a granule of pollen, and ultimately absorbing the parent cell, or resolving it into a surrounding viscous element. The granules either remain single, as in Misleto, or adhere to each other in masses, then called pollinia, which include a definite or irregular number of granules. The pollinia vary in different plants, two being usual in Orchis morio, four in Cattleya, and eight in Laelia. In the Acaciæ, ringens, decipiens, and linearis, 8, 12, and 16 respectively, are united together. Each of these masses contains myriads of prolific atoms; and out of the two from the Orchis mentioned above, Amici calculated 120,000 in a single stamen. Hassal affirms that each stamen of a Pæony produces

21,000 grains, and a single head of Dandelion upwards of 240,000 in number.

The surface of the pollen is either smooth, or depressed, or raised in rounded pores. There is a single depression in Welsh onion or Cibroule, three in Trailing Bindweed, and in other plants as many as twelve are to be met with. The rounded pores are also various; there is only one in Cock's-foot grass, and, when more numerous, they are scattered over the surface in a regular or irregular manner. Spines, hairs, and crests, often surround the grains with their projections.

The usual forms of pollen grains are ellipsoidal, as in Marsh Hibiscus; trigonal, with convex sides, as in Broad-leaved-tree Primrose; square cylindrical, as in Common Virginia Spiderwort; and polyhedral, as in Garden and Wild Succory. Spheroidal and oval, with attenuated extremities, are also frequent. As these forms offer a delightful study for microscopic observation when a reflected light is employed, we subjoin the following select and useful list for further illustration :—

Anagallis,..........................	Pimpernel.
Arbutus,..........................	Strawberry-tree.
Campanula trachalium & nitida,	Bell flower.
Cineraria maritima,..............	Sea cineraria.
Circea lutetiana,..................	Common enchanter's nightshade.
Coreopsis lanceolata,.............	Spear-leaved coreopsis.
Digitalis purpurea,................	Purple foxglove.
Elymus sabulosus,.................	Lyme grass.
Fuchsia globosa and caccinea,...	Fuchsia.
Geranium sanguineum,...........	Bloody crane's bill.
Hieraclium sibiricum, ...	Siberian cow parsnip.
Lychnis flos cuculi,...............	Red meadow lychnis.
Malope trifida,.....................	Three-lobed malopé.
Pancratium declinatum,..........	Pancratium.
Salvia interrupta,................	Sage.
Scirpas romanus,.................	Club rush.
Solanum dulce,.....................	Nightshade.
Symphytum officinale,............	Comfrey.
Viola tricolor,.....................	Violet.

The pollen grain, when minutely examined, is seen to be invested with two coverings; the external, called *extine* (*exto*, to stand outward), which gives form and colour to the grain, and the internal, or *intine* (*intus*, within), which is then transparent and flexible. In many aquatics, as Common Grass-Wrack, the intine alone exists. But between these envelopes some anatomists (Fritzsche) have professed to detect two others, known as *intextine* and *exintine*, formed by foldings of the outer and inner membranes. The formation of the inner coats takes place first, the others owing themselves to a subsequent deposition in the parent cell; but observations are awanting to prove whether this process is conformed throughout species to the manner of growth in exogens and endogens, when taken as wholes.

6. The discharge of the pollen seed is called *dehiscence;* but in a large sense, the diffusion following on it comprises the superficial outlets that are formed, the internal propulsion employed to evacuate by them, and the organic irritability and foreign agencies contributing to the result. The pistil has also an active influence, but the respects in which it aids the dissemination of pollen will be traced under that organ.

(1.) Outlets to promote the escape of the pollen are made by clefts, lids, hinges, or pores. Clefts take effect along the face of the groove formed by the membranous divisions already referred to. When the lobe is erect, the dehiscence is longitudinal, as in Byrsonima bisorniculata. It is transverse in Common Ladies' mantle.

A sort of blade, opening from a joint, forms a lid, which separates from the apex; and this dehiscence is called *circumscissile* (*circum*, around, and *scindo*, to cut), or *operculate* (*operculum*, a lid). The Gamboge plant, Passion flower, and Gourd, present instances.

Hinges of the anther are formed by a valve rolled up on the outside of a suture. In Barberry there is one, and in Laurel two such valves, for each lobe.

Pores are glandular holes placed on the base or apex of anthers, but sometimes on the sides, as in Misleto. Each loculus opens by a single porous duct in Pyrola rotundiflora; by two in Vaccinium uliginosum; and in Tetratheca juncea by four uniting in a single passage at the top. Heath Rhododendron and Potato supply other examples.

(2.) It will be remembered that the spiral tissues of the endothecium were left entire after absorption of the cells which surround them; and at this point a beautiful contrivance of nature comes into view, which it is scarcely possible to find surpassed, as a striking proof of the perfect adaptation of organic matter to the end of its creation. The absorbent powers of the pistil, imbibing the superfluous moisture of all the surrounding parts, the spiral vessels of the anther come into play as tiny springs, acquiring their power by combination; and after contracting sideways, they at last succeed in severing the walls of each lobe, which burst and scatter their pollen at the exact time the female organ is prepared for its reception. Such elastic filaments are to be seen in Common nettle and Pellitory of the wall. In Marsh Parnassia and Rue, the anther scatters its contents during a certain state of expansion of the parts. The pollen sacs of Kalmia spring to the pistil on the same principle, and similar phenomena are observed in Canadian Dogwood, &c.

(3.) But apart from elasticity, which depends on the mere mechanism of the organs, there is a principle of chemical irritability concerned in fertilization. The operation in this case results from the stimulation of contact. This will be obvious in the following instances :—When the recurved valves, covered over with pollen, have attained to ripeness on the Common Barberry, their pressure upon the base of the pistil has the effect of moving the stamens towards it, and causing their discharge. In Australian Stylewort, a common column projecting from the flower envelopes the stamens and pistil; and when the base of the former is brought into contact with the latter by the progress of growth, or from any other cause, whether permanent or temporary, the stamens jerk to the side with a suddenness that ruptures the lobes, and scatters the pollen. Such apparatus and devices are greatly diversified for insuring the fecundation of species; we may be allowed, therefore, simply to refer to the Marsh Parnassia, Common Rock-rose, and Unequal-leaved Ruellia, for exhibiting staminal movements of a similar character.

(4.) The general position of the line by which the anther opens, lies towards the female organ, so that the pollen emitted by the one may fall readily upon the other; but to this arrangement there are many exceptions, and we find the organs occasionally so placed that it is impossible to account for their united action without the agency of wind, water, and insects. The simplest case of this description occurs in the Hazel and Willow, where the organs of reproduction stand separate in different flowers; fertilization, therefore, always precedes production of the leaf, and the diffusion of the pollen from this cause meets with no interception. The pollen of Firs, during spring, is strewed upon the ground in enormous quantities, in guarantee of its application, notwithstanding the presence of leaves, and is even sometimes carried to great distances, like yellow showers. In aquatics, such as in African Hydrocharad, and in Two-stamined Vallisneria, the female plant is borne on a spiral stem, which accommodates itself to the depth of the water; but the male plant which grows near, becoming detached at the period of flowering, from the bottom to which it was bound, floats to the surface, and performs the nuptial rite before it is caught by the rippling wave, again to sink and reproduce itself in mud. The Italian, Micheli, who was unacquainted with the idea of the sexes, has represented this natural fact with a grace of imagination that breathes of the kisses and mystery of a human love.

Bees, aphides, spiders, and flies, resort to the Orchidaceous tribes of every country, for the sweets secreted within the flower. In several species of Birthwort, the anthers are placed below the stigma of the female, and the whole is shut up within the tube of the calyx, the interior of which is furnished with deflexed hairs; insects, therefore, entering in search of food, apply the pollen in their efforts to escape. A small beetle, native to the wilds of Kamschatka, by its predatory thefts, facilitates

the increase of a lily to which the population of Greenland owe their winter subsistence.

When the efforts of the plant world seem thus to be set at nought, foreign forces come to her aid. The breeze carries the pollen of the date-tree across the desert, and the wave wafts the prolific fruit of the palm to distant shores. The roving bee, too, in supplying the wants of its young, is necessarily securing the production of seed. In these simple events we behold a marvellous combination of effects, and a group of independent results, worked by one harmonious machinery, alike to the glory of the Great Disposer and the wisdom of that primeval law—"Let the earth bring forth grass, the herb yielding seed, and the fruit-tree yielding fruit after his kind, whose seed is in itself on the earth."

COMPENDIUM OF LOGIC.

CHAPTER III.

THE SYLLOGISM ANALYSED—QUANTITY AND QUALITY OF PROPOSITIONS—SINGULAR AND COMMON TERMS—REALISM AND NOMINALISM—ANALYTICAL OUTLINE CONCLUDED.

In last chapter we commenced our analytical outline by showing that all reasoning might be reduced to the syllogism; and, after giving some examples, and explaining the *sorites* and *enthymeme*, we briefly considered the objection urged by Dr. Campbell and others, to every syllogistic argument, namely, that it begs the question, and necessarily, therefore, can prove nothing. This objection was sufficiently answered by showing that the syllogism proves whatever can be proved by argument, being in reality the mere development of all the steps that are taken—either expressed or understood—in common reasoning. The value of the syllogism, therefore, chiefly consists in its exposing to view every part of the argument, so that if a fallacy exist therein, it may, by applying the subsidiary rules of the science, be at once detected.

We now pursue our analytical inquiry, by proceeding to a closer inspection of the different parts of the syllogism, taking as the subject of analysis our first and simplest example:—

1. All men are mortal:
2. Napoleon is a man; therefore,
3. Napoleon is mortal.

Here, it will be seen, that the argument consists of three propositions or statements—the first, as already explained, being termed the major premiss; the second, the minor premiss; and the third, the conclusion. Each of these propositions consists, in logical language, of a subject, copula, and predicate. In the first proposition, or major premiss, the expression or term, "all men," forms the *subject*, and the term, "mortal," the *predicate;* these are united by the copula "are," which means that the attribute mortality is *predicated* of "all men." "Napoleon is the *subject* of the minor premiss, and in this proposition it is predicated of him that he is included in the class, "all men," of whom it has already been predicated that they are mortal. Hence follows the third or concluding proposition, namely, that "Napoleon is mortal," in which it will be seen that the subject, "Napoleon," is the same as that of the minor premiss, and the predicate, "mortal," the same as in the major premiss.

Again, it will be found that the three propositions embrace only three ideas or terms, a fact which may be rendered still more obvious by generalizing the argument, and substituting symbols for words. Thus let B represent "all men;" C, "mortal;" and A, "Napoleon;" then we have the syllogism generalized as follows:—

All B are C:
A is one of the class B;
Therefore, A is C.

These three terms A, B, C, are named respectively the minor, the middle, and the major terms. The subject of the conclusion is the minor (A), and the predicate of the conclusion the major term (C). The middle term (B) is that by which the major and minor are connected or linked together, and hence it is sometimes called the *argument.*

This middle term is the point on which many fallacies turn, supposing the assumed premisses true. We beg, therefore, to impress upon the reader the infinite importance of giving attention to this point, in trying the validity of any argument. Undoubtedly the first essential in a question of fact—though not in regard to the soundness of the reasoning—is the truth of the premisses; but this being proved, granted, or assumed, the next subject for immediate inquiry is the kind of connection that subsists between the middle term and the other two—for *the middle term ought to be a class in which the minor term is included (or from which it is excluded), and of which the major term may be affirmed (or denied).*

Thus, in the preceding example, A is the subject, and C is the predicate of the conclusion. But A is included in the class which forms the middle term, B, according to the minor premiss; and C, in the major premiss, is affirmed of the class, B; hence, we justly infer in the conclusion (according to Aristotle's Dictum) that C may be affirmed of A.

Or, recurring to the verbal syllogism, "All men are mortal," &c.—and admitting in this case the truth of the premisses, we go at once to the conclusion, "Napoleon is mortal," in which the major term, "mortal," is predicated of the minor term, "Napoleon." To satisfy ourselves that the conclusion is valid, we must look in the premisses for a middle term to form a connecting link between the subject and predicate of the conclusion—a term expressive of a class in which "Napoleon" is included, and of which "mortal" may be predicated. This is found in the term, "all men," for the minor premiss—"Napoleon is a man,"—is equivalent to the proposition, "Napoleon is one of the class 'all men;'" and again, in the major premiss, it is assumed or affirmed of the class, "all men," that they are "mortal." This syllogism, therefore, completely realizes the requirements of Aristotle's Dictum, given in the preceding chapter, but which we shall repeat in this place, to bring it immediately under the reader's attention in applying it to the cases that follow:—

"Whatever is predicated (*i. e.* affirmed or denied) universally, of any class of things, may be predicated, in like manner, (*i. e.* affirmed or denied,) of anything comprehended in that class."

Now, let us try by this fundamental test, one or two of the apparent arguments given in the form of syllogisms towards the conclusion of our second chapter. First—

All wise legislators suit their laws to the genius of their nation:
Solon did this;
Therefore, Solon was a wise legislator.

Here, also, we assume the premisses as true, and proceed to try the conclusion by the rule laid down in the Dictum. "Solon" is the subject of this conclusion, or the minor term, and it is predicated of him that he was "a wise legislator." Now, let us see to what class Solon is stated to belong, and whether, as the Dictum requires, the same thing, "Wisdom in legislation," is predicated of that class. The minor premiss only affirms that Solon belongs to the class of those who "suit their laws to the genius of their nation;" but nothing whatever is predicated of this class. It is not said in the major premiss, that those who do so are wise legislators, but that wise legislators do so, which is a very different statement. Lycurgus, for example, suited his laws to the genius of his nation, and yet it may be doubted whether he was a wise legislator. This might be an indication of wisdom—wise legislators do so—yet there may be other defects in the laws which would disentitle their author to the character of a wise legislator. Without denying the truth of the conclusion, we therefore affirm that this syllogism exposes a fallacious argument, when tried by the infallible test of the Dictum; for no class is stated in the premisses in which Solon is included, and at the same time, of which class, "wisdom in legislation" is predicated.

Thus, it will readily be perceived, that the preceding *apparent* argument exactly corresponds to the following form of words, the absurdity of which is manifest, in this case, from

the absurdity of the conclusion—"All vegetables grow: animals grow; therefore, animals are vegetables." This illustration may be given as a kind of *reductio ad absurdum;* and yet if we compare it with the former example, in which the fallacy is less obvious, because the conclusion, as well as the premisses, are all true propositions; we find that the reasoning in the one case is just as sound as in the other. If it follows from the premisses, in the first example, that "Solon is a wise legislator," so must it follow from the premisses in the second, that "animals are vegetables."

Try by the same test the following example, which has likewise been already given as an instance of inconsequential reasoning:—

> Every rational agent is accountable:
> Brutes are not rational agents;
> Therefore, brutes are not accountable.

Here, we may admit the premisses at once: the conclusion also is a true proposition; yet it will be found on examination that it does not follow from the premisses. It draws, as the apparent inference, that brutes are not accountable beings. Now, in what class are brutes included? It is stated in the minor premiss that they "are not rational agents," that is to say, they are *merely excluded* from the class of rational agents, which class is stated in the major premiss to be "accountable;" but, although the fact may be perfectly true, it is nowhere stated in the premisses that beings which are not rational agents are not accountable. Hence, it cannot be inferred from the premisses—however true in point of fact—that brutes are not accountable beings.

The following *reductio ad absurdum*, which has been given as an illustration of this kind of fallacy in reasoning, will be found exactly to correspond. "Every horse is an animal: sheep are not horses; therefore, sheep are not animals." Here, the fallacy is more obvious, because the conclusion is ridiculous; yet the reasoning, if it may be called so, is exactly the same in both cases.

And now, having given these examples of fallacies, tested by Aristotle's Dictum, this may be a fitting place to call attention to what has been termed by logicians the *quantity* and *quality* of propositions.

When anything is predicated of a whole class, the subject—or the term expressive of that class—is said to be "distributed." Thus in the proposition, "man is mortal," the term, "mortal," is affirmed of the subject *universally*—that is to say, it is affirmed of the whole class. The subject, "man," is therefore distributed in this case, but not so the predicate, "mortal," which may be affirmed of all animals whatever; and therefore, as a predicate, its meaning or applicability is not exhausted by its application to man—that is to say, it is not a distributed term. Again, when we say, "food is necessary to life," we mean that *some* food is necessary, not that *all* food is necessary; so that in this case the subject is not distributed. And neither is the predicate distributed here—that is to say, the term, "necessary to life," is not exhausted in its application to food; for not only food, but air also is necessary to support existence. Indeed, we shall afterwards see that, in affirmative propositions, the predicate (or that which is affirmed of the subject) is only distributed in some exceptional cases.

Now, when there are two propositions, in one of which the *subject* is distributed, and in the other not, these propositions are said to differ in *quantity*.

But let it be noted, that the distribution or non-distribution of the *predicate* is quite independent of the *quantity* of the proposition. This entirely depends on the *quality*, in which respect two propositions are said by logicians to differ, when the one is *affirmative*, the other *negative*. Thus, the propositions, "Man is sinful," and "No man is free from sin," are propositions differing in quality, though similar in their signification, and similar also in quantity. The *subject* is distributed in both cases; for, by the first proposition, we mean that all men are sinful, and by the second proposition we mean exactly the same— "freeness from sin" is denied of all men. But in the first proposition, "man is sinful," the predicate is *not* distributed, because there may be other beings sinful besides man—the fallen angels, for example. We merely assert, in this *affirmative* proposition, that man is sinful; we do not deny that the term, "sinful," may be applied to other beings. In the second proposition, however, "No man is free from sin," the term, "man," is excluded from the whole class of beings "free from sin." In this case, therefore, the predicate, as well as the subject, is distributed; and so, by parity of reasoning, in all other *negative* propositions. The distribution or non-distribution of the predicate depends, therefore, on the *quality* of the proposition.

This distribution or non-distribution of terms, is a point of the utmost importance—a point on which many fallacies turn; and, therefore, is deserving of the reader's careful attention. When we say that "*all* men are mortal," or, "*some* men are born to fortune," the distribution of the subject is clearly expressed, in the first case, by the word "all"—its non-distribution in the second by the partitive "some;" but many affirmative propositions occur—indeed, we may say, a large majority, in which it is left to be inferred from the meaning, whether the subject is distributed or not. Thus, in the following apparent argument:—

> Food is necessary to life:
> Corn is food;
> Therefore, corn is necessary to life—

both the premisses are evidently true; and the conclusion appears at first sight a perfectly legitimate inference, according to the rules of the syllogism; yet the conclusion is a false proposition, and therefore an unwarrantable inference, for life can be supported without corn. The fallacy in this case arises from the fact, that the middle term, "food," is not distributed, either in the major or minor premiss, whereas, to render the conclusion valid, it ought to be distributed at least in the major premiss. When we say that "food is necessary to life," we mean that *some* food is necessary—not *all* or *every kind of* food; hence, it by no means follows that, although corn is food (that is to say, *some* food), corn is necessary to life; for nothing is affirmed of the whole class, but only of a portion of the class under which corn is included.

The *quantity* of the proposition, when not distinctly expressed by the qualifying adjectives "all," "every," "some," &c., must therefore be carefully observed, especially with reference to the middle term, which, in the major premiss, ought to be always distributed to render the conclusion valid; for, unless so distributed, it cannot represent an entire class, to which the subject of the minor premiss may be referred; and therefore the requirements of the Dictum cannot be satisfied in this case.

The *quality* of the proposition, that is to say, its affirmative or negative character, is likewise a point of the greatest importance, as affecting the distribution or non-distribution of the *predicate*. The fact has been already stated that, in affirmative propositions, the predicate is rarely distributed, while it is always distributed in those of a negative character. The reason of this will be obvious on reflecting, that if anything is merely affirmed of another, the proposition does not imply that it may not be affirmed of something else. Thus, when we say that "Man is rational," nothing is stated which involves the conclusion that the attribute reason is *confined* to man, and therefore the predicate, "rational," is evidently not distributed. Innumerable classes of rational beings may exist, and "man" is merely affirmed to be one of these classes, or to belong to the genus of rational beings—to constitute a *part* of that class. But when we say that "no brutes are rational," we mean and affirm that brutes are excluded from the *whole* class of rational beings. In the latter case, therefore, and only in the latter, the predicate, "rational," is distributed.

We have now arrived at that point in our analysis, at which we are enabled to trace to their source, in a strictly philosophical manner, the fallacies of many apparent syllogisms—fallacies turning on the non-distribution of one or more of the terms, and especially of the middle term. Thus, in the following instance:—"Vegetables grow: animals grow; therefore, animals are vegetables"—both the premisses are here affirmative; and, therefore, the middle term, "grow," being the predicate in both, is *not* distributed in either. Hence, there can be no

legitimate inference, except that animals and vegetables *do resemble each other* in belonging to the class of things that grow. Or, again, when we say that "wise legislators suit their laws to the genius of their nation," the proposition, being affirmative, does not distribute the predicate; hence, it may apply to legislators not distinguished by wisdom; and, therefore, though the same may be affirmed of Solon, it does not follow *from the premisses*, that he was a wise legislator.

Generally, therefore, the inference may be drawn, or, in other words, it may be inferred as a general rule, that when the middle term is the predicate of two affirmative premisses, no valid conclusion follows—the argument, however plausible or specious, is no argument at all.

But, if we change the quality of one of the premisses—that is to say, if either the one or the other be thrown into a negative form, then we may legitimately draw a valid inference. Thus, if we say—

> *No unwise* legislators suit their laws to the genius of their nation:
> Solon did so;
> Therefore, he was not an unwise legislator.

Here the conclusion is perfectly valid; because in the major premiss, which is now a negative proposition, the predicate is fully distributed, being denied of the *whole* class of unwise legislators. But it is affirmed of Solon that he "suited his laws," &c.; therefore, he is likewise excluded from the whole of the same class; that is to say, he is "not an unwise legislator."

An equally valid, though opposite conclusion will follow, by throwing the minor premiss into a negative form, which, however, totally alters the meaning. Thus—

> All wise legislators suit their laws, &c.:
> Solon did not do this;
> Therefore, he was not a wise legislator.

Here, although the middle term is still the predicate of both premisses, yet we are enabled to draw a valid conclusion, because, in the minor premiss, Solon is excluded from the whole class of those who adapt their laws to the genius of their nation; and as, in the major premiss, *all* who legislate wisely are affirmed to belong to this class, it follows that Solon is excluded from the whole class of wise legislators. This may be false as a proposition; but, as an inference or conclusion from the premisses, (all that logic pretends to determine), it is quite legitimate.

With reference to the statements of certain logicians, that, in affirmative propositions, the predicate is *never* distributed, some doubt may exist. It cannot be denied that it holds as a general rule; but as to the statement that it holds universally, we have some misgivings, though this is asserted by Whately in such terms as the following:—"The learner," he says, "may perhaps be startled at being told that the predicate of an affirmative is *never* distributed, especially as Aldrich has admitted that accidentally this *may* take place: as in such a proposition as 'all equilateral triangles are equiangular'; but this is not accurate: he might have said that in such a proposition as the above the predicate is *distributable*, but not that it is actually distributed: *i. e.* it so happens that 'all equiangular triangles are equilateral;' but this is *not implied* in the previous assertion; and the point to be considered is, not what *might be* said with truth, but what actually *has been* said. And accordingly mathematicians give distinct demonstrations of the above two propositions."

Now, we are willing to admit the force and validity of this reasoning with reference to the special example given, namely, that "all equilateral triangles are equiangular;" for, although it happens in this case that the converse of the proposition is true, or that "all equiangular triangles are equilateral," yet, this is clearly a mere accidental occurrence, and is not implied in the terms of the original proposition itself. It is different, however, with another example adduced by the same high authority:—"So also," he adds, "if I say that 'Romulus was the first king of Rome,' this implies, from the peculiar *signification of the words*, that 'the first king of Rome was Romulus.'" Here we are much at a loss to discover what it is that Archbishop Whately means by the peculiar *signification of the words;* for these words appear to us really to imply that the predicate is fully distributed in this case, and that the converse of the proposition is affirmed in the proposition itself. This example essentially differs from the former, for when we say that "all equilateral triangles are equiangular," it is not by any means involved in the statement, nor is it even self-evident, that "all equiangular triangles are equilateral;" but when we say that "Romulus was the first king of Rome," it clearly and necessarily follows, or rather is implied in the expression itself, that "the first king of Rome was Romulus."

So, when we say that "the Egyptians were the first civilized people," or that "the Highland brigade was foremost in the battle of the Alma," or that "Man is the ruler of the lower animals,"—the predicate in each of these propositions appears to be fully distributed; for each of the predicates will only apply to the subject of which it is expressly enunciated, and therefore the converse of each proposition is implied in the proposition itself. In this case, indeed, the subject and predicate are said to be *convertible terms;* but still what is said or affirmed of the subject is not less truly a predicate, and this predicate, moreover, is not less truly distributed.

We would therefore insist, that when the predicate expresses the superlative degree, or generally when it is a term which may take the place of the subject, and which can be applied to nothing else, it is in that case distributed, even in affirmative propositions. This we would state as an exception to the *general*, but not (as we think) *universal* rule, that, in affirmative propositions the predicate is *not* distributed.

But these considerations have brought us down to the most elementary part of our subject, namely, the distinctions of terms. In the course of our rapid analytical survey, we have explained, in the first place, what the syllogism is, and what it is fitted to accomplish; then we have considered the proposition with reference to quantity and quality—especially as bearing on the question of the distribution of terms. It now, therefore, only remains, to complete our analytical view of the subject, that something should be said as to the nature of terms themselves—of the kinds of things which are capable of being made *predicates*, or of having anything predicated of them; that is to say, *subjects*.

"Logic," says Mr. Stuart Mill, "is the theory of proof. But proof supposes something provable, which must be a proposition or assertion; since nothing but a proposition can be an object of belief, or therefore of proof. A proposition is, discourse which affirms or denies something of some other thing. This is one step: there must, it seems, be two things concerned in every act of belief. But what are these things? They can be no other than those signified by the two names, which being joined together by a copula constitute the proposition. If, therefore, we knew what all names signify, we should know everything which is capable either of being made a subject of affirmation or denial, or of being itself affirmed or denied of a subject."

Now, the word "name," or "names," in the preceding extract is used in the sense which we have hitherto expressed by the word "term," or "terms." It is thus more exactly defined by Hobbes:—"A name," says that writer, is a word [or words] taken at pleasure to serve for a mark, which may raise in our mind a thought like to some thought we had before, and which being pronounced to others, might be to them a sign of what thought the speaker had before in his mind." To this very simple definition of a name or term, we may add that the word, or words, of which it consists, may be either *written* or *pronounced.* In the one case, the idea of the thing expressed by the mark is conveyed to the mind through the organ of sight, in the other through the organ of hearing.

In this sense, all the words in every language may be regarded as names or marks of certain things, or ideas, or feelings. A few of them, indeed, such as the particles *of*, *to*, *truly*, &c., can only be regarded as parts of names, and cannot be employed *alone* as the terms of a proposition, except in speaking of the words themselves, as when we say—"*Of* is a conjunction," or "*whereas* is an English word." Adjectives may form the predicate, but not the subject of a proposition, except in the same verbal sense. We cannot say, "agreeable is

pleasant," unless as a mere definition of the word *agreeable*. The same remark applies to the inflected cases of nouns and pronouns.

But our limits forbid us to enter minutely into such details in this analytical outline. We shall therefore confine ourselves at present to that distinction which exists between singular and general terms—the former denoting individuals, the latter expressive of classes; so that the distinction between them requires to be clearly understood, to complete our idea of the syllogism, as it is expressed in the Dictum.

A *general name* may be defined, a name which is capable of being truly affirmed, in the same sense, of an indefinite number of things, while an *individual* or *singular name* is a name which is only capable of being truly affirmed, in the same sense, of one thing. All things are capable of being named; and separate or singular names might be applied to every individual object in the universe; but no human memory could retain them, and such a system of naming could only result in confusion. We, therefore, give separate distinguishing names only to those individual objects of which we have frequent occasion to speak in their *individual* capacity; thus, there is a name for every person and for every remarkable place and object—not perhaps a separate name in every case, for different persons and places and objects may be denoted by the same name; but still the variety and distinction of singular names are sufficient to indicate in any particular instance the person, the place, or object, which the name may be intended to designate. Thus, we distinguish individual *persons* by their names, John, Thomas, Buonaparte, Cæsar, &c.—names which may apply to different persons, but which can be affirmed *in the same sense* only of one individual. Remarkable objects, and even remarkable animals, are likewise distinguished in the same manner. Every considerable mountain and river has a name appropriated solely to itself, or by which it is at least sufficiently distinguished from other rivers and mountains. Domestic animals have generally familiar names by which they are addressed or spoken of. Every considerable eminence, every farm, or township, or glen, or rivulet, is known, in its own locality, by some particular denomination, by which it is distinguished from all others, and which, as in designating persons or animals, is termed in this case a *proper name*.

But still there is a great variety of objects to which it would be utterly impossible, as well as absolutely useless, to give individual names. We cannot name every star in the firmament, every tree in the forest, every cavern or rock in the mountain, every boulder, or pebble, or grain of sand in the valley. But finding, for example, an object, which we name a *stone*, and finding a variety of other objects, which, though differing in some respects, bear a general resemblance to that which we have so named, we give the same denomination to every individual of the *class;* and this becomes the general or class name, such as a *stone*, a *river*, a *man*, a *tree*, a *mountain*. In the case of persons universally, and also in the case of remarkable places and objects, a *proper* or particular name is given to each individual, as has been already remarked. *Proper* names are therefore singular terms, even when, as in the case of the Andes or the Hebrides, they indicate a number of objects of the same description; because they are in that case regarded as a *single* group or collection. But proper names do not exhaust the meaning of singular terms. When we wish to denominate a river, a diamond, or a mountain, which has not a name of its own, or in other words, a proper name, like the Thames, the Koh-i-noor, or Mount Vesuvius, in that case we borrow the class name, to which we prefix a demonstrative pronoun, or some other definite expression by which it is distinguished or *marked out* from all other objects of the same class. Thus we say, "this river," "that mountain," "the star that is nearest to the north pole," "the present emperor of Austria"—all of which are singular terms, because they can only be applied *in the same sense* to one individual object or person. Singular terms (including proper names) may therefore be composed of several words, though neither a singular nor a general term can form a complete sentence, because we have seen that all propositions are made up of two terms.

A general or common term is, as already defined, a name which is capable of being truly affirmed, *in the same sense*, of an indefinite number of things. Thus the word "man" may be affirmed of every individual of the human race, however much one individual may differ from another individual in features, stature, or character. All figures bounded by three straight lines, however dissimilar in shape, are known by the general designation of "triangles." All eminences rising to a considerable height are termed "mountains." Thus the innumerable objects of creation, as well as the various feelings and emotions that pass through our own minds, are grouped or distributed in classes, the names of which are *common terms*—that is to say, they are terms *common* to every individual of the class to which each belongs. The general characters of classes are known, because they are *comparatively* few in number, and therefore when we know the particular class to which an individual object belongs, the general character of the object is known also. Hence the immense importance to science, of what is termed *classification;* because when we can predicate of any substance, or any subject of reasoning, that it is included in a class which is distinguished by certain properties, then, by a purely syllogistic process, we arrive at a knowledge of the properties of that subject itself.

The process by which we classify or generalize, is termed "abstraction," (Lat. *abs*, *traho*, I draw off,) because in abstraction we *draw off* and *contemplate separately* some property or part of an object presented to the mind, disregarding the rest of it. Thus, in generalization, we abstract or draw off from different objects that part in which they agree, and, disregarding their points of difference, we class them as sweet or bitter, acid or alkaline, round or square, however dissimilar they may be in other respects. It is by the power of abstraction, and hence of generalization, that man appears to be especially distinguished from the lower animals; and civilized, educated man from the uncivilized and ignorant of his own species.

From this explanation of the theory of generalization, the reader will perceive that the same objects may be distributed in different classes according to the quality or qualities selected as the principle of classification. Thus "man" may be considered as a "biped," abstracting from his other properties the fact of his walking upon two feet, and then he will be classed with the feathered tribes, or any other two-footed animals, if such exist; or he may be viewed as a "mammal," and then he will be classed (as he really is by the zoologist or physiologist) with other animals of that description, in which even whales are included. Or, he may be thought of as simply an animal, and then he will be classed under that designation, with all other animals whatever. Or, he may be studied in a nobler light—regarded as a rational, intellectual being, abstracting the qualities of reason and intelligence from those that connect him with the lower creation, and then he will be classed with the superior beings, or even, to some extent, with Deity itself, as having been formed in the image or likeness of his Maker.

Inanimate objects may be variously classed in the same manner. An orange may be classed among round objects, or among things that have a fragrant odour, or those that are distinguished by a yellow colour, or it may be classed with fruits in general, or it may be merely regarded as a product of the vegetable kingdom.

These considerations throw light on a question to which we adverted in our first chapter, (in giving a historical outline of logic,) as forming the subject of much acrimonious controversy during the scholastic era, or the middle ages. We allude to the dispute between the Nominalists and Realists, the latter of whom, as we then stated, maintained that a general or common term, such as a man, a river, a mountain, indicates a really existing *thing*, which must be present to the mind of all who think of the idea expressed by these general terms, and which must exist also in each individual, man, river, and mountain, otherwise the general term could not be applied to each. Aristotle never inculcated this doctrine. It seems to have been borrowed from the mystical visions of Plato, who held that in the mind of the Deity existed the primary forms or archetypes to which these general terms correspond, and which—or their shadow resemblances—are present to the mind of every one who thinks of the idea expressed by them. Thus

it was maintained by the logicians of the Realist school, that when any number of individuals think of a mountain in its general sense—that is to say, without special reference to any one mountain in particular—the same idea must be present to the mind of each, and that idea must correspond to something that actually exists in every mountain, not less truly than a singular term has one corresponding object of which it expresses the conception. The Nominalists maintained, on the contrary, that general names, or common terms, are merely designations of classes or groups of individuals, resembling each other in certain features, and do not correspond to any real *thing* existing in the objects themselves, but merely represent a vague idea of any one of these objects, without its individual peculiarities.

The creed of the Nominalists is that which is now universally received. It is obvious that the words *river* and *mountain* are merely the *names* of an indefinite number of objects, each of which resembles, in its general features, all the other individuals of the class to which it belongs, and that when we think of a mountain, for example, without having special reference to any one mountain in particular, the only idea in our mind is a vague and shadowy conception of a high elevation or protuberance on the earth's surface. This conception will be different in different minds, according to the aspect of the mountains which each has been most accustomed to see, or to read of, or hear described, or according to the force of the imaginative faculty in each. On this point Whately justly remarks—"The fact is, the notion expressed by a common-term is merely an inadequate [incomplete] notion of an individual; and from the very circumstance of its inadequacy, it will apply equally well to any one of an indefinite number of individuals of the same description; to any one, in short, possessing the attribute or attributes that have been abstracted, and which are designated by that common-term. For example, if I omit the mention and the consideration of every circumstance which distinguishes Ætna from any other mountain, I then form a notion (expressed by the common-term *mountain*) which *inadequately* designates Ætna (*i. e.* which does not imply any of its peculiarities, nor its numerical singleness), and is equally applicable to any one of several other individuals"

The Realist doctrine would scarcely be worth confuting, were it not that it occupied so large a space in the fierce controversial warfare of the middle ages. If anything were wanting to prove its absurdity, it is to be found in the now acknowledged fact to which we have already adverted, namely, that classes may be multiplied to any extent, by abstracting any quality or qualities we please from an indefinite number of objects, and classing the objects under some common-term, according as they *do*, or *do not*, possess such quality or qualities. Thus, we find the same identical objects grouped into different classes, and therefore under different common-terms, according to the purpose intended by the classification. The diamond is classed by the jeweller among precious stones; by the chemist it is classed among combustibles, under the name of carbon. The common-term, *mountain*, embraces "Ætna;" so does the common-term, '*burning-mountain;*' so does the common-term, '*part of the globe.*' The common-term, *element*, as understood by the ancients, could only be affirmed of four things—air, earth, fire, and water. Now, it is known, that of this very limited group, three at least are *not* elements, while, on the other hand, the number of real or presumed elementary substances is now extended to upwards of fifty. Where could be the really existing *thing* corresponding to the term, *element*, when it was so wrongly applied, because so erroneously conceived, by the philosophers of former ages?

Realism, therefore, has been justly exploded as a mere philosophical refinement, resting on no substantial basis. We have adverted to it much more minutely than its acknowledged unimportance deserves, chiefly as a curious illustration of those metaphysical subtleties with which the scholastic logicians were perplexed, while, at the same time, it has given us occasion to explain what is really meant by a class, and what is expressed by a common or general term—a point of very high importance to a clear comprehension of reasoning, as set forth in the syllogism.

Here we may conclude our analytical outline—an outline imperfect indeed; but in which we have traced the process of reasoning down from its complete form in the syllogism, to its component elements or parts in the proposition and term. In executing this operation, we have touched upon most of the preliminary questions that lie, not only at the threshold, but even at the very basis of the science of logic—and these being now removed out of the way, we shall be enabled, in the next chapter, to commence our synthetical compendium with fewer philosophical perplexities to solve, and less to distract our attention from the rules of logic as an art.

THE SCIENCE OF PHRENOLOGY.

ORDER I.—FEELINGS.

GENUS II.—SENTIMENT.—(*Continued.*)

17. HOPE.—Hope is situated on each side Veneration. Dr. Gall considers hope as belonging to every faculty, but Dr. Spurzheim controverts this. Every faculty being active, produces desire. Acquisitiveness produces the desire for property; Love of Approbation for praise. This is very different from Hope, which is a sentiment necessary for every situation in life. Hope has been well considered as the sheet-anchor of the soul: what would existence be worth in this world without such a feeling or sentiment? The man who is deficient in this sentiment, is always doubting of success in any of his enterprises. If success does crown his efforts, he feels surprise, and wonders at the accomplishment of an object, which the man with large Hope would scarcely have doubted. The man who is deficient in Hope, is prone to despond; he can see but little, if anything, to cheer his progress through life. If he has large Cautiousness, he is always fearing; if to this is added large Destructiveness, he has the essential gloom which predisposes to solitude and suicide.

As a religious sentiment, associated with Benevolence, Veneration, and Conscientiousness, it is of the most exhilarating character. Connected with the ideas which man forms of a future state, it is Hope which gives substance to faith. It is replete with bright imaginings. It rises superior to opposing difficulties; it looks onward to the brightness of a future state, and anticipates the realization of its delights in a world where pain and sickness never comes. The man in whom this sentiment is suitably associated, and which predominates over Cautiousness, has no fear of the grave, because his desires never expect to receive full gratification until he reaches the world beyond it, and the glorious prospect of his future existence renders him patient under all the cares and the sufferings of this.

"O, there are days when love and light
Are to our pathways given,
When Hope takes her exulting flight
On eagle's wings to heaven!—
Days when a thousand smiles unite
The peace-lit brow to bless,
Chaste heralds of a new delight,
Bright harbingers of happiness."

We consider Hope to be one of the most useful of the religious sentiments.

Like every other feeling, it is liable to abuse. When in too active a state, that is, when inordinately developed, and not properly controlled by the reflecting faculties, it may lead to the supposition that everything which is needful will be supplied without the care and labour of him who is the subject of it, and thus a fatal security be induced which may cause much misery. The man who dabbles in lotteries, the man who is to be found at the gaming-table, will be sure to have this sentiment very largely developed, with probably equally large Acquisitiveness, and but feeble Conscientiousness. Rash, inconsiderate, and speculative persons have this sentiment large, and the reflecting faculties weak. Take the following oriental legend as a sample:—

Abdallah stood in his little shop, behind a basket of brittle

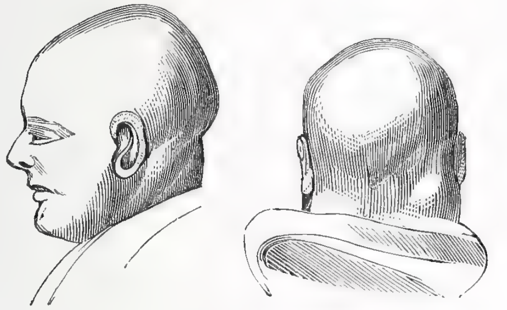
ware, which he hoped speedily to turn into money, and he began to hope aloud. I shall, I hope, get a good sum for these, and I shall then buy a richer stock. These I shall equally soon dispose of, and sell at a double profit. I shall then take a larger shop, and lay in a still richer stock. My stock will go off as quickly as usual, and I shall then have it in my power to marry Selima. She shall reside in an elegant house, for by that time I shall be a rich and prosperous merchant. She will, of course, bring me a son, and he will become a great man surely; he will be doubtless a vizier, and places will be at his disposal. I think I see Selima now approaching to beg me to use my influence with my son, to procure a place in the Sultan's retinue for one of her favourite slaves. I am too grave to listen to her. She importunes me, and I raise my foot to drive her away, using, at the same time, the words, "Woman, my son cannot get places for all your favourites." Thus Abdallah hoped aloud, but his action was suited to his word, for at the last sentence he unhappily raised his foot, and kicked the basket of brittle ware, the foundation of all his hopes, into the middle of the bazaar, and thus marred all his brilliant prospects.

Thus it is, to a greater or less extent, with all those whose hope is too energetic, and though—

> "By the breath of fortune blown,
> Their airy castles are o'erthrown,"

they recommence their ideal structures, and hope, like Jacob Faithful, to meet with better luck next time.

Mary M'Innes, while under sentence of death for murder, never lost the hope of being pardoned. In her the organ was very large. On the contrary, it was small in David Haggart, and he entertained no such hope.



18. Marvellousness.—Marvellousness is situated immediately below Hope, on each side of Benevolence and Imitation. This organ disposes to belief in the unseen world, and to the acknowledgment of the existence of a Divine Being. The great apostle of the Gentiles gives three distinguishing principles as essential to the formation of the Christian character—faith, hope, and charity. He describes charity as the greatest. If we look at the situation and connection of these three organs on the chart, we see that Marvellousness is in close connection with Hope. In fact, they run into each other. Charity, or Benevolence, is the centre. These three sentiments are also essentially connected with Veneration, or reverence for the Great Supreme, and Conscientiousness, or love of truth. These constitute the religious group of organs. That they are capable of abuse from disease or over-excitement, cannot be doubted. But, in the legitimate exercise of their functions, they are undoubtedly the foundation of the religious character, and are to be considered as the more spiritual powers of the mind.

The organ of Marvellousness is also useful in the moral character, equally with Veneration, which induces respect to others; and Benevolence, which prompts to deeds of charity and love.

It is a satisfactory evidence to many, that Marvellousness excites the mind to pursue investigation, and new discoveries are powerfully aided and furthered by this sentiment. Marvellousness also is a powerful stimulant to invention; it is ever prompting to the discovery of something new. Marvellousness also assists Ideality. The unseen world, with its beauteous scenes, pass before him in whom it is freely developed, and he is thus enabled to transfer the ideal of beauty, and the ideal of the sublime from his own brain, to that of those who may read or hear him.

Enthusiasm, in its true and legitimate sense, has its origin in this organ; but with the following extract from Hayden's "Physiology for the Public," we will close this article—the organ is not considered as fully established:—

It was the remark of Napoleon, that, in war, the moral are to the physical means as three to one—so highly did that consummate general rate the influence of mere mind on the issue of any great military enterprise. Now the same will often be found to hold good in the more peaceful operations of the healing art.

It was observed that the officers engaged in the last war, bore the fatigue, hardships, and privations inseparable from a campaign, at least as well, if not better, than the soldiery, although the former were in many instances the élite of the land, reared in the lap of luxury, with all the care and downy comfort which ingenuity or wealth could devise or afford.* How are we to account for this elastic endurance of unwonted bodily suffering? We are to find its explanation by reference to the mind, which has now its turn. I have already shown that the state of the corporeal functions influences, to a humiliating extent, the moral portion of our being: you have here to look at the converse of the proposition; the body now is enabled to endure the most unusual suffering, by the aid of the attributes of mind, call that agency and those attributes what you will, which are the secret springs of human actions and of man's endurance.

> "Life's smallest miseries are perhaps its worst:
> Great sufferings have great strength: there is a pride
> In the bold energy that braves the worst,
> And bears proud in the bearing; but the heart
> Consumes with those small sorrows and small shame,
> Which crave, yet cannot ask for sympathy:
> They blush that they exist, and yet how keen
> The pang that they inflict!"—L. E. L.

Shall we call this supporting spirit pride or patience—emulation or energy? It is easy to assign the final cause, that "God fits the back to the burden, and tempers the wind to the shorn lamb;" but it is not so easy to name that attribute which is the offspring of God's grace. We will venture to call this divine essence—enthusiasm, without which there is no greatness of character. It is the elevating principle of the best—the highest aspirations alike of religion, of morals, and of intellect.

We speak now, remember, of enthusiasm in its best acceptation, which Johnson, our great lexicographer, defines to be "elevation of fancy, exaltation of ideas."

> . . . . . "At last sublim'd
> To rapture and *enthusiastic* heat,
> We feel the present Deity."—*Thomson.*

[We have already alluded to this attribute; but we cannot resist the present opportunity of putting before you our notions in reference to the extensive range of its application.]

The fondest thing in nature—the most disinterestedly fond—is a mother of her offspring. This, generally, is alike true amongst all tribes of animals, as we are fully prepared, from experience, to admit. It is equally true that the end of existence is enjoyment; consequently, pleasure and pain should be the most operative and influential agents in inducing us to pursue and persevere upon the one hand, and to decline and desist on the other.

* Witness the sufferings, privations, and hardships borne by nobles, by pilgrim kings in the Crusades. See them again in the pursuit of fame or fortune, or the defence of fatherland, of home, of family, endowed with almost supernatural strength and untiring vigour; now buffeting the boisterous billows—the saucy waves; next, storming and scaling the so-called impregnable fort and rampart; and anon, with "will invincible," facing the deadly foe, and conquering those incorrectly surnamed *invincible;* lastly, weary but triumphant—making earth their couch—the starless heavens their canopy—their martial cloaks their covering.—*Introductory Lecture in Medical Times, November* 14, 1843.

Do but balance these—pleasure and pain—in the scale of an anxious mother's existence; how much will the latter preponderate! Yet observe how an occasional transient gleam of sunshine, shed over the pallid countenance of the sickly but smiling child, lights up the mother's care-worn countenance with the radiance of hope and joy, which repays her for days and nights—nay, months and years of devoted solicitude and harassing watching. It is obvious that reason is not the uplifting influence here: the soul-supporting spirit is instinctive, absorbing love—"less akin to earth than heaven"—which inspires that exalted train of ideas we so justly call the enthusiasm of the mother.

Observe, in the next instance, the child—the mere child—its young mind expanding—bursting into beauty like the opening bud under the sun's vernal influence; its nature ardent, generous, so innocent, so unsuspecting; its ecstacy to caress and be caressed. The lively senses, that drink in with eager thirst the things of the outward world—all delightful, because they are gilded by the sunny light of fairy fancy and *bright enthusiasm.*

Providence has closely linked industry and happiness, and ordained them to be Siamese sisters. "The gods," says the poet, "have placed labour and toil in the way leading to the Elysian fields." Whether we labour with our hands or with our heads, or with both together, or now one and again the other, we would have you undertake your work, more especially the mental portion of it, with energy, ay, with enthusiasm—the soul-awakening spirit that fires the youth—implants the "will invincible"—bids the march of mind never halt, and cheers on industry and genius in their glorious struggle up the rough and rugged steep that leads to knowledge and to virtue's temple.

In riper years—in manhood—what marks the man of genius—what the man of soul? What raises him above the vulgar herd? What elevates him so high above the heads of those who are merely rich in pelf, but poor indeed in worth? What gives the fire to music, to poetry, and to thought? What makes the great be good, the good be great? Shall we not call that spirit divine enthusiasm?

In the heart's affection, where shall we look for the secret subtle essence, the thrilling soul-felt influence, which makes woman a spirit of light and loveliness?—that sheds a hallowed atmosphere of "sainted chastity" around her, and bids man almost worship the idol object of his love? Is it not because her thoughts—her feelings—her sentiments—are the purer offspring and the brighter emanation of an unshackled enthusiasm?

Finally; should we not cherish, then, this glorious attribute—the parent of all that's good, that's great, that's noble, and that's generous: the blessed emanation of Divinity itself; that teaches [ransomed] man to rise above his fallen self, and proudly feel how grovelling and unsatisfying are things of earth; and bids the imprisoned and anxious eye of Time to look to heaven and to eternity for the enjoyment of unalloyed enthusiasm!

19. Ideality.—Ideality is situated above the temples, in the course of the temporal ridge of the frontal bone. It is in the vicinity of Hope and Marvellousness, with Cautiousness behind, and Acquisitiveness just below it. It was for a considerable time before Dr. Gall marked this organ as established; and when he did, he was still inaccurate in naming it; he distinguished it as the organ of poetry; Dr. Spurzheim has given to it the more just and elegant name of Ideality. He remarks on its functions, that it exalts the other powers, and makes us enthusiasts; gives warmth to our language, energy to our actions, and fires us with rapture and exultation, or poetic imagination, fancy, and inspiration, as it is termed.

Poetry, it is evident, neither consists in versification, nor in rhyming, since prose writings may be full of poetry, and verses show none of its glow or its colouring.

This feeling makes man aspire after perfection and look for things as they ought to be. In the arts, it causes the taste for sublimity.

The want of this feeling leaves the mind to operate by the means of its other elements, and deprived of exaltation.

It was very largely developed in Tasso. It gifts its possessor, when suitably associated and aided by other powers, with that sublimity of description, that symmetry of form, that beauty of imagery, that grandeur of description, that polish of

language, which may be considered as the soul of eloquence. It imparts to Veneration a deep reverence and fervent adoration; to Language, elegant and choice selection; to Benevolence, refined tenderness and sensibility; to Love of Approbation, a keener relish for approval. It aids the powers which delight in fiction; it adds and deepens the novelty inspired by Marvellousness; it etherealizes and elevates still higher Hope; and, in short, it is the creator of a world of fancy, in which it loves to model every ideal excellence and perfection. There is a space marked on the busts with a (?), to denote that its functions are unascertained. The late Dr. Maxwell of Glasgow, who paid much attention to this portion of the brain, and to the manners and habits of those persons in whom it was largely developed, gave to it the name of Conservativeness. One very striking instance of it came under our own observation. Having predicated the character of a very beautiful poet, we marked this portion of the brain at 22, but without giving any idea of its functions or power, otherwise than stating to its possessor, that he was very largely endowed with what Dr. Maxwell termed Conservativeness (?). A few days after, we received the following letter:—

"Glasgow,———

"Dear Sir,—That portion of my brain which lies between Ideality and Cautiousness, to which some have given the name of Conservativeness, is, according to your own measurement, so very large as to be marked 22, your average size being indicated by 14.

"According to my interior experience, there has been, as long as I can remember, one faculty at work in my mind more powerfully than any other, and which (whatever that faculty may be) has all along indicated itself to my own perceptions, by conferring on me certain peculiarities, of the principal of which the following is a concise statement:—I experience the most intense delight in the preservation of little things, especially, such as form a record of past states and circumstances, such as I perceive have no value attached to them by people in general. I have a copy of everything I ever wrote, however trifling. I have copies of my principal letters. I have a copy of every letter or card I ever received, with the exception only of those addressed to my firm when in business. I have innumerable scraps of paper, on which ideas were jotted down just as they occurred, and which I was fearful might not occur again in the same form or degree of intensity. I have begun scores of works, and written hundreds of title pages! I have a great many different places into which I thrust my papers, according to the subject, &c., and feel delighted when those various departments increase on my hands. Often I get harassed by anxiety, lest any small thing should be neglected or misplaced. I have kept a journal of my life, both as to feelings and events, without interruption, since the 12th year of my age. I am, besides, very careful of

clothing, &c.; and it distresses me to see anything wasted, especially beautiful white writing paper: so I write as much as possible on useless fragments of bills, letters, &c. Though I should lose a thousand pounds, it would yield me pleasure the very same day to save a few sheets of writing paper, or note down a thought I considered worth preserving. I believe that, in reality, all things are equal in size, value, and the joy they give; that it is only comparatively they are different.

"These peculiarities may be produced by my organization in general; but I think they are to be traced chiefly to the organ of Conservativeness. I leave you to judge in regard to this matter, and to make what use you please of these few hurried observations.

"Very sincerely,

"J. R. S."

The proximity of this portion of the brain to Cautiousness strengthens Dr. Maxwell's view. It is probable, too, that as Ideality embraces both the sublime and the beautiful, that the organ of "Conservativeness," which lies between Ideality and Cautiousness, may partake of the quality of both; since there are many who may enjoy the awful sublime, who do not so keenly appreciate the beautiful.

It is almost impossible to illustrate the ideal of beauty, since what appears beautiful to one person peculiarly organized, will to another have very few attractions.

A beautiful landscape will excite one train of feelings, and the individual in whom the pleasurable emotions are produced, will, in addition to form, size, and colouring, combined with Ideality, always be found endowed with *locality*.

The ideal of sublimity is different. It may be some of us have witnessed, if not participated in, the perils of a storm at sea. After having seen the giant waves lashed into fury by the fierce and angry power of the wind; the flashes of lightning more rapid and intensely brilliant than the blasts of a metallic furnace; the thunder more loud and appalling than a park of the mightiest artillery, and the rain descending in such whelming torrents, that to appearance, the windows of heaven were again opened to spread desolation on the earth—with such sublime convulsions before us, we may have beheld at a little distance from an iron bound rocky shore, a ship with its crew of terrified living creatures—"mount up to heaven, go down again to the deep, reeling to and fro, staggering like drunken men, they are at their wits' end, their souls melted because of trouble." The sublime of ideality may here be depicted in the storm, to those who are in safety; yet it produces emotions of fear and anxiety for the safety of the human beings exposed to the convulsion of the elements, which must be the direct opposite of the ideal of beauty.

It appears, then, that one of these kinds of ideality may be possessed without the other; that is, one man may be more moved by witnessing the awful and terrible sublime; while another will be more influenced by the beautiful.

Shakespere was an individual in whose brain appeared every mental and ideal excellence. In English literature he reigns without a rival. As a sample of his general powers, in which, though he knew nothing of phrenology, its principles are most correctly delineated, we quote a passage from Richard II., Act V., Scene 4:—

"I have been studying how I may compare
This prison where I live unto the world,
And for because the world is populous
And here is not a creature but myself
I cannot do it. Yet I'll hammer it out;
My *brain* I'll prove the female to my soul,
My soul the father, and these two beget
A generation of still breeding thoughts,
And these same thoughts people this little world
In humours like the people of this world,
For no thought is contented. The better sort,
As thoughts of things divine, are intermixt
With scruples; and do set the *Word* itself
Against the *Word*.
As thus: *Come little ones;* and then again,
It is as hard to come as for a camel
To thread the postern of a needle's eye.
Thoughts tending to ambition, they do plot
Unlikely wonders; how these vain weak nails
May tear a passage through the flinty ribs
Of this hard world, my rugged prison walls,
And for they cannot—*die* in their own pride.
Thoughts tending to *content*, flatter themselves
That they are not the first of fortune's slaves,
Nor shall not be the last:—like silly beggars
Who, sitting in the stocks, refuge their shame
That many have and others must sit there;
And in this thought they find a kind of ease,
Bearing their own misfortunes on the back
Of such as have before endured the like.
Thus play I in one person, many people,
And none contented: Sometimes I am a king,
Then treason makes me wish myself a beggar,
And so I am: Then crushing penury
Persuades me I was *better* when a king,
Then am I king'd again: and by and by
Think that I'm unking'd by Bolingbroke,
And straight am nothing."

Of the many illustrations of ideality, which in the course of our phrenological prelections we have used, there is not one that has been received with greater favour, than the lines by Richard Lane, Esq., on the statue of his dead child. In this poem, ideality is seen extending its influence to the social affections, amativeness, philoprogenitiveness, inhabitiveness, and adhesiveness; calling in the aid also of benevolence and veneration, occasionally heightened in beauty by a dash of sadness or cautiousness:—

I saw thee in thy beauty, bright phantom of the past;
I saw thee for a moment, 'twas the first time and the last;
And, though years since have glided by of mingled bliss and care,
I never have forgotten thee, thou fairest of the fair.

I saw thee in thy beauty, thou wast graceful as the fawn,
When in wantonness of glee, it sports along the lawn;
I saw thee seek the mirror, and when it met thy sight,
The very air was musical with thy burst of wild delight.

I saw thee in thy beauty, with thy sister by thy side,
She a lily of the valley, thou a rose in all its pride:
I looked upon thy mother, there was triumph in her eyes,
And I trembled for her happiness, for grief had made me wise.

I saw thee in thy beauty, with one hand among her curls,
The other with no gentle grasp had seized a string of pearls;
She felt the petty trespass, and she chid thee though she smil'd,
And I knew not which was loveliest—the mother or the child.

I saw thee in thy beauty, and a tear came to mine eye,
As I press'd thy rosy cheek to mine, and thought ev'n thou could'st die!
My home was like a summer bower by the joyous presence made,
But I only *saw* the sunshine, and *felt* alone the shade.

I *see* thee in thy beauty, for there thou seem'st to lie,
In slumber resting peacefully; but, oh! how chang'd thine eye—
That still serenity of brow—those lips that breathe no more,
Proclaim thee but a mockery of what thou wast before.

I see thee in thy beauty! with thy waving hair at rest,
And thy busy little fingers folded lightly on thy breast;
But thy merry *dance* is over, and thy little race is run,
And the mirror that reflected two, can now give back but one.

I see thee in thy beauty, with thy mother by thy side,
But her loveliness is faded, and quelled her glance of pride;
The smile is absent from her lip, and absent are the pearls,
And a cap almost of widowhood conceals her envied curls.

I see thee in thy beauty, as I saw thee on that day—
But the mirth that gladden'd then my home fled with thy life away;
I see thee lying motionless upon th' accustom'd floor,
But my heart hath blinded both my eyes, and I can see no more.

Ideality may exist where there is no disposition to poetize: where the individual may be so influenced by the substantialities of life, as to have little inclination for the set rules and fetters in which the imagination is bound down when poetically disposed. In Lord Brougham, there is a large endowment of this organ, and his eloquence is, by all, universally admitted. The law is confessedly a subject, upon which the pleader may bestow considerable eloquence with the happiest effects; but constituted as it is at present, those who have the least to do with it, are the safest, as well as the happiest. The rich man may go to law, but even he gains only a loss. But if the poor man go to law, he loses all. Men of all parties see that this is the truth, although the fear of change prevents them from rendering any assistance to alter it. Among the efforts which have been made to render law cheap, and justice fully and freely administrated, none have more perseveringly and disinterestedly pursued the course of amelioration than Lord Brougham,—and the peroration of his speech, on the state of the law in England, is not only strikingly illustrative of his benevolence and conscientiousness, but also of his ideality—here are his words:—"A great and glorious race is open before

you; you have it in your power to make your names go down to posterity, with the fame of more useful importance attached to them than any parliament that ever preceded you. You have seen the greatest victor of the age, the conqueror of Italy and Germany, who, having achieved triumphs more transcendent than any upon record, said, 'I shall go down to posterity with the code in my hand.' You have beaten that warrior in the field, try to rival him in the more useful arts of peace. The glories of the regency, gorgeous and brilliant as they were, will be eclipsed by the milder and more beneficent splendour of the king. The flatterers of the Edwards and the Henries compared them to Justinian; but how much more justly may it not be applied to our own sovereign, when to his other glories this shall truly be added. It was said by Augustus, that he found Rome of brick and left it of marble—an honourable boast, and one which veiled many of the cruel and tortuous acts of his early course;—but how much higher and prouder would be the boast of our king, to have it said, that he found law dear and left it cheap—that he found it a sealed book, and left it an open letter—that he found it the patrimony of the rich, and left it the security of the poor,—that he found it a two-edged sword in the hands of the powerful, and left it a staff for the comfort of the feeble and the friendless."

In persons where ideality is small or feebly developed, much wonder is experienced, that such subjects as the one which has occupied our attention in this article, should be considered so interesting and attractive. The late Mr. Cobbett was very moderately developed in this organ, and his remarks on Milton's sublime epic, ludicrously exhibit his deficiency:—"It has," says he, "of late years, become the fashion to extol the virtues of potatoes, as it has been to admire the writings of Milton."—(Let it be remembered that he denominated the potato, "the accursed root;" and the bitterness of his associating the poetry of Milton with the accursed root, will be more distinctly recognized.) "God, Almighty, and all foreseeing, first permitting his chief angel to be disposed to rebel against him; his permitting him to enlist whole squadrons of angels under his banners; his permitting the devils to bring cannon to this battle in the clouds; his permitting one devil or angel, I forget which, to be split down the middle, from crown to crotch, as we split a pig; his permitting the two halves, intestines and all, to go slap up together again, and become a perfect body; his then permitting all the devil-host to be tumbled headlong into a place called hell, of the local situation of which no man can have an idea; his causing gates (iron gates, too) to be erected to keep the devil in; his permitting him to get out, nevertheless, and to come and destroy the peace and happiness of his new creation; his permitting his son to take a pair of compasses out of a drawer, to trace the form of the earth; all this, and indeed the whole of Milton's poem, is such barbarous trash,—so outrageously offensive to reason and to common sense, that one is naturally led to wonder, how it can have been tolerated by a people amongst whom astronomy, navigation, and chemistry are understood. But it is the fashion to turn up the eyes when *Paradise Lost* is mentioned; and if you fail herein, you want taste; you want judgment, even, if you do not admire this absurd and ridiculous stuff, when, if one of your relations were to write a letter in the same strain, you would send him to a mad-house, and take his estate."

This is the case with all matter-of-fact writers. If you compare the portrait of Locke with that of Chaucer, the difference of organization will immediately appear. The organ is rarely found in any great proportion among criminals, among the most atrocious criminals it has ever been deficient. The same may be said of the rude, uncivilized tribes of mankind. Mr. Combe observes—that "joined with love of approbation, form, colouring, and the other knowing faculties, using constructiveness, as their instrument, it produces all the ornaments of dress and architecture, and is the fountain of painting and sculpture. Those persons, therefore, who declaim against ornament, ask us to shut up one of the greatest sources of enjoyment. An elegant *vase, couch*, or *chair*, fashioned in all the proportion which constructiveness, aided by ideality and form, can attain; or the human form attired in dress, in which grace, utility, and beauty, are combined, is an object which our faculties feel to be agreeable; the pleasure arising from it is natural, and of so excellent a quality, that it is approved of by the intellect and all the moral powers." *

According to most travellers, there is no country in the world, where the homes of the working classes are so comfortable as in England. This we believe to be the truth. But so far as a taste for the beautiful is concerned, there is still ample room for improvement. In the heart of a populous town, little can be done comparatively; but in the suburbs, how many plots of ground do we see contiguous to dwelling-houses, which might, with a small outlay of labour and expense, be made to teem with beauty and fertility. And even among those who do cultivate a garden, there is still a great want of taste. How often is the eye offended by an unsightly dead wall, or a decaying thorn hedge—when these might be easily screened by some creeping plant; a few scarlet beans, for instance, would very soon throw a verdurous mantle over them, and the eye, instead of resting with pain on dirty brick or gritty sand-stone, might repose with pleasure on refreshing green leaves and bright scarlet blossoms. The cottages of the French and Swiss peasantry are said to be much more picturesque than those of the same class in England; but they are certainly less comfortable. It appears to us quite possible, to unite both comfort and beauty, without any additional expense, save that of a little labour. The day is not far distant, when all classes will acknowledge the important truth, that beauty is useful.

It has been said that from the sublime to the ridiculous is but a single step; but this results from incongruity of association. Here is an instance:—

Can I e'er forget *that* face?
  With those eyes so softly beaming:
That form, so beauteous, full of grace,
  Like a sunbeam o'er me streaming.
No! while the sun on us looks down,
  I'll love thee, till my life-thread's spun,
But as to lend thee half a crown,
  It can't, no how, at all be done.

Or, take the following prose illustration—"The shades of night gathered thickly around: dark masses hung portentously over the earth; the wind whistled mournfully over the horizon, while the deep-toned thunder, in muttering accents, proclaimed the fearful tempest's near approach. As the big drops of rain began slowly to descend, with a look and a manner not to be mistaken—a little pig curled up his tail and ran like—Old Harry."

The abuses of this faculty are clearly of a mischievous tendency; calculated to lead the possessor astray by excessive sensibility, and the imagination of arriving at a refinement of elegance and excellence not to be met with in this mundane sphere. Of this highly excited disposition was Rousseau:—"The impossibility of finding any beings worthy of myself, threw me," says he, "into the regions of fancy; and seeing that no existing object was worthy of my delirium, I nourished it in an ideal world, which my creative imagination soon peopled to my heart's desire. In my continual ecstacies, I drank in torrents of the most delicious sentiments which ever entered the heart of man. Forgetting altogether the human race; I made society for myself of perfect creatures, as celestial by their virtues as their beauties, and of sure, tender, and faithful friends, such as I have never seen here below. I took such delight in gliding along the air, with the charming objects with which I surrounded myself, that I passed hours and days without noticing time; and losing the recollection of everything, scarely had I eaten a morsel, but I burned to escape and return to this enchanted world."

SHORT READINGS IN ELECTRICITY.

BY MR. R. SMITH, BLACKFORD.

1.

Frictional Electricity.—The science of Physics is of vast extent, and each step which the investigator takes in its territories, serves

System, Vol. I., p. 398.

to show him in how small a degree it has been explored. Electricity alone, as one of its branches, presents us with a wide and extended range of study, and to its consideration we propose to devote a brief space as a species of receiver for the summing up of what has been done in its pursuit.

Electricity possesses the properties of composing and decomposing bodies, causing the union of simple substances to form compounds, and the separation of compounds into their elementary constituents; its secret influence is actively engaged in the development of crystals, from the feather-formed snow-flake, to the hardest and most compact prismatic gem, at one time exercising its mighty powers in the production of the storm, at others, presiding in terrific grandeur over the volcano's eruption, dealing death and destruction to all who may happen to be in the course of its progress; observe it again so completely under the control of man as even to be employed in the healing art, the printing of cloth, the moving of machinery, and the conveying of intelligence from one place to another. Before proceeding with a description of the experiments illustrative of the properties of electricity, it will be necessary to give a glance at the history of the science. Electricity, from the Greek word *electron,* (amber,) is the name by which this branch of natural philosophy is designated. Thales of Miletus, the celebrated founder of the Ionic school of philosophy, was acquainted with the power that amber possessed, when rubbed, of attracting light bodies, and also the benumbing effect experienced on touching the torpedo, (electrical eel,) and he ascribed these results to the presence of a soul or essence, which when impassioned or excited by the frictional operation, went forth to bring back the small particles of matter that were floating around. We find in the writings of Pliny and Theophrastus, a few remarks on the power of amber and the lyncurium stone, of attracting light substances by means of friction, but no attempt is made to explain this property. Dr. Gilbert published a treatise on magnetism in the year 1600, in which he added greatly to the then number of substances capable of drawing light bodies to them when excited by friction. Newton, Boyle, Guericke, and various other philosophers, contributed to extend a knowledge of the interesting subject also; but it was not till 1720, that the dawn of real electrical science appeared, when its foundation was laid by Mr Stephen Gray. This celebrated experimentalist pointed out the difference between electrics and non-electrics; conductors and non-conductors. The next that followed in his wake was Du Fay; he ascertained in the year 1736 that conductors when insulated, can be excited by friction, and that there were two kinds of electricity, one produced when glass is rubbed with woollen cloth, which he called vitreous; the other kind generated when any resinous substance is rubbed with warm flannel, hence called resinous; and that bodies possessing the same kind of electricity, repel each other, and attract those that have a different kind. In 1746, the Messrs. Muschenbroeck, Allamand and Cuneus, performed a number of experiments which paved the way to the introduction of the Leyden phial—they suspended a gun-barrel by silk cords from the ceiling of the room, the one end of it being brought near a revolving globe of glass, and the other end being caused to pass into a glass bowl, filled with water, held in the hand of the experimenter; when the other hand was made to touch the gun-barrel, an electric shock was the result. M. Muschenbroeck, in a letter to M. Reaumur, describes the effects of a shock taken in this manner. "I felt myself struck in my arms, shoulders and breast—I lost my breath, and it was two days before I recovered from the terror and effects of the blow." Undoubtedly this novelty was greatly magnified in the description of Muschenbroeck, as thousands of shocks are taken now-adays by a far more powerful manner, without producing any subsequently painful sensations or alarm. As Mr Noad justly observes, "it serves to show how cautious we should be in receiving the first accounts of extraordinary discoveries, where the imagination is likely to be affected." In 1754, Benjamin Franklin published his experiments and observations at Philadelphia, on the phenomenon of the electric shock—the supposition that only one electric fluid existed—the impossibility of accumulating electricity in bodies having points—the analysis of the Leyden phial, and the discovery of the identity of electricity and lightning. This he proved by drawing the lightning from the clouds by means of a kite, and performing with it the same experiments as with electricity produced by the electric machine; a discovery which will render his name ever memorable in the history of science. Franklin's theory was brought forth, shrouded in the garb of mathematics, in 1759 and 1771, by Mr Cavendish and Epirus; and Lord Mahon, in 1779, published a work in which he explained that the electricity contained in an electric atmosphere surrounding an excited body, diminishes inversely as the square of the distance Next in order stand the interesting discoveries of Coulomb which were published in 1785 and 1786; this philosopher made three additions to the science, which constitute the first principles of electricity—1st, attraction and repulsion, and that they follow the same law as that of gravitation; varying inversely as the square of their distance—2nd, excited bodies that are insulated, gradually give out their electricity to the surrounding air, which is never altogether free of conducting substances—3rd, when any body is charged with the electric fluid, such as a ball, the whole of it is spread over the surface; there is none of it penetrates into the interior, consequently a thin hollow ball will contain precisely the same amount of electricity as one that is solid of the same size. It was the opinion of electricians for a considerable time, that electricity could only be excited by sharp friction, but modern discoveries have proved that it can be elicited by chemical action, by electro-dynamic induction, by breaking and renewing the contact with the poles of a compound magnet by means of the armature, by changing the temperature of bodies, by the muscular action of certain fishes, and by the evaporation of fluids and the evolution of gaseous bodies under certain circumstances all of which will be described hereafter.

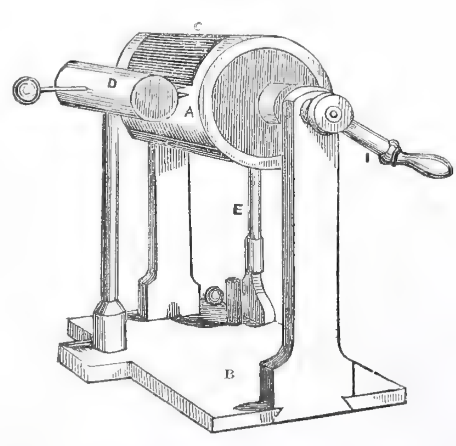
Having given a short detail of the history of common electricity, we now proceed with the most general and remarkable facts connected with it—1st, The excitation of electricity—2d, The distribution of it — 3rd, The various apparatus illustrative of the subject—4th, A review of the theories which have been advanced.

It has been previously mentioned, that the earliest fact connected with the science of electricity, was the power that bodies possessed, of attracting substances when excited by friction. The following simple experiments will serve to illustrate this principle;—If a piece of glass, amber, or sealing-wax, is rubbed with a piece of woollen cloth, a very singular property is acquired; this property is exhibited when the body submitted to friction, is held over small pieces of gold leaf, hair, feathers, paper, &c., as they will be immediately attracted by it, some of them adhering to the surface, others being repelled, or thrown off. Place a small shred of paper upon a table, and hold a piece of excited sealing wax over it, the paper will be instantly attracted, and remain in contact with the wax for a short time, when it will again return to the table, and after remaining a second or two upon the table, ascend to the wax, and will continue to be alternately attracted and repelled, till the accumulated electricity spread over the surface of the wax has passed to the table, or more properly, until the electrical equilibrium is restored. The phenomenon of attraction and repulsion is exhibited in a more interesting and striking manner by suspending a small ball of cork or pith, by a long thread of silk, and, after rubbing a glass tube or rod, present it to the ball, the ball will be attracted; after they have remained in contact for a short space of time, if the glass is withdrawn, and again presented to the ball, the latter will be repelled instead of being attracted. The ball may be deprived of its electricity, by touching it with the finger, and when this has been done, if a piece of sealing wax is presented to it instead of the glass rod, the same phenomena will ensue. On the first application of the wax, the ball will be attracted; and on the second, repelled. It is evident, that both these electric bodies possess the property of attracting another body before communicating their own electricity, and in the second place they repel the body after they have given out a quantity of their electricity to it. Rub a piece of writing paper with caoutchouc, and present the rubbed side to the ball, and the result will also be as above. The property communicated to wax by friction, is different from that communicated to glass, which may be rendered apparent by holding excited sealing wax on the one side of the ball, and excited glass on the other; the ball will vibrate from the one to the other, being alternately attracted and repelled. Sir David Brewster says, in the article Electricity, *Encyclopædia Britannica,* "excited glass repels a ball electrified by excited glass. Excited wax repels a ball electrified by excited wax. Excited glass attracts a ball electrified by excited wax. Excited wax attracts a ball electrified by excited glass." So that it may be either supposed that there are two kinds of electricity, according to the theory of Du Fay, or with that of Franklin, that there is only one kind, but in different states. In excited glass there is a superfluity, and in excited wax a deficiency. Some substances remain longer in contact with an electric body than others, and two substances that have been in contact with the electric, of course repel each other mutually—this phenomenon is best observed, if large electrics are used. If a cylinder of sulphur is rubbed in a darkened chamber, flashes of bluish coloured lambent light will appear on its surface. On presenting a metallic ball, or the knuckle to it, a number of sparks may be obtained, and if brought near to the face, a tickling sensation is felt in the skin. When a metallic globe is suspended in the air by a silk cord, and

rubbed by an electric, it acquires the same properties as an electric,—instruments termed electroscopes are constructed on the same principle as that of the above experiment. The principal electrical substances are precious stones, amber, glass, talc, sulphur, rosin, gum-lac, silk, furs, and almost all vegetable substances that have been dried or baked, with the exception of charcoal. It has been already observed, that when an excited body was brought near the cork or pith ball, it was first attracted, and then repelled; if the electric be removed, and another ball of the same material be presented to it, which had no previous communication with an electric, these two balls will attract each other. Again, if a third ball be presented to the second, the same action is repeated, and so on in succession, but every ball that is employed indicates a diminution of power. It would appear that the intensity is diminished by the distribution of the electric fluid, amongst a number of bodies. An electrified ball cannot be deprived of its electricity by touching it with a rod of glass or wax, but it will be instantly deprived of it by touching it with a rod of metal, or the fingers; consequently glass and wax are non-conductors, and metals and the human body are conductors. The following is a list of conductors and non-conductors collected by Sir David Brewster, and placed in the order of their conducting and non-conducting power. The conductors are silver, copper, lead, gold, brass, zinc, tin, platina, palladium, iron, heated and cold, charcoal, plumbago, acids concentrated, powdered charcoal, diluted acids, saline solutions, metallic ores, animal fluids, hot-water, river-water, ice above 13 degrees Fahrenheit, snow, living vegetables, living animals, flame, smoke, steam, soluble salts, rarefied air, vapour of alcohol, vapour of ether, moist earths, anthracite, powdered glass, flour of sulphur, resin rendered fluid by heat, glass heated to redness.

Non-conductors, are shell-lac, amber, resin, sulphur, wax, jet, glass vitrifications, mica, diamond, transparent gems, various minerals, raw silk, bleached silk, dyed silk, wool, hair, feathers, dry paper, parchment, leather, air and all dry gases, baked wood, dry vegetable bodies, porcelain, dry marble, and siliceous and argillaceous stones, camphor, caoutchouc, lycopodium, dry chalk, lime, phosphorus, ice below 13° Fahrenheit, ashes of animal bodies, ashes of vegetable bodies, oils, dry metallic oxides. Friction is always necessary for the development of common electricity, and for the display of the electric phenomena, on an extended scale, the aid of mechanism, has been put in operation. Various contrivances have been devised, termed electrical machines; they are all, however, constructed on one principle. The cylindrical machine was suggested by the glass globes used about the middle of the last century, by Mr Hauksbee. This cylindrical machine consists of a cylinder of glass mounted on an axis, and furnished with a handle, supported on upright pillars of glass or baked wood. Other two cylinders of metal or wood covered with tin foil, equal in length to the glass cylinder, are placed one on each side parallel with it, and supported upon insulating pillars also. To one of these conducting cylinders is attached a leather cushion stuffed with hair.

Fig. 1.



The other conductor contains a row of metallic points to draw the electricity from the glass, a flap of oiled silk is fastened to the cushion and stretches over the top of the glass cylinder in order to prevent the dissipation of the electric fluid before it reaches the metallic points.

The annexed diagram, fig. 1. represents the cylindrical machine, A, is the glass cylinder, B, the stand, C, the silk flap, D, the prime conductor, E, the negative conductor containing the rubber, and I, the handle of the machine.

The plate machine possesses considerable advantages over the cylindrical machine, as a greater quantity of electricity can be obtained from an equal surface of glass. This is produced in consequence of rubbers being placed on both sides of the glass plate, however, for general experimental illustration, the cylindrical machine is preferable to the plate one, being easier to insulate, so as to exhibit the properties of negative electricity. Another disadvantage attending the use of the latter is, that, when overheated, the glass plate is apt to crack at the centre, which proceeds to the circumference, and the machine is rendered useless.

Fig. 2.

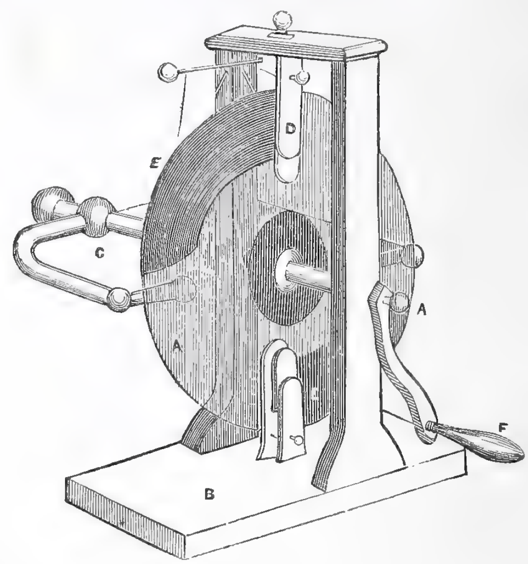


Fig. 2 is a representation of the plate machine; A, the glass plate; B, the stand; C, the conductor; D D, the two rubbers; E E, the silk flaps extending from the rubbers; F, the handle. Electrical machines have been constructed similar to the plate one, by substituting a circular piece of strong paper board instead of the glass plate, and caoutchouc rubbers. Whatever form or materials may be used in the construction of a machine for producing electricity by friction, it must possess a substance capable of excitement, an exciting substance or rubber, and an insulated conductor for receiving and retaining the electric fluid. When an electrical machine is to be put in operation, it should be warmed by a current of warm air; if this is not convenient, it may be placed before a common fire, but care should be taken that it is not exposed to a strong heat; it must only be gently warmed, frequently changing its position, in order to bring all its parts to a general and equal temperature. The cushion should be coated with an amalgam, which is generally composed of tin foil, and mercury. Mr Noad recommends it to be prepared as follows:—Equal parts of tin and zinc are melted together, and after shaking it in a wooden box with twice its weight of mercury, it is then rubbed in a mortar with a little lard until it forms a paste. The author has found that 1 part of zinc and 3 parts of mercury, omitting the tin, forms a very good amalgam. The chemical action of the amalgam greatly facilitates the development of electricity from the cylinder; when the cylinder of an electrical machine is driven round, the glass becomes positively, and the cushion negatively excited, the metallic points convey the positive charge from the glass to the prime conductors; the other conductor connected with the rubber becomes deprived of its electricity to a certain extent, and becomes negatively electrified. If one end of a wire is connected with the prime conductor, and another wire with the negative, and a light ball suspended by a thread from each of the other ends of the wires, when brought near each other, the balls will be attracted, being oppositely electrified. After the action of the machine has gone on for some time, the rubber and negative conductor become exhausted of their electricity; and must be supplied with more from the earth, by forming a communication between the rubber

and the ground, when a constant stream of positive electricity will flow to the prime conductor. By reversing the arrangement, an equal quantity of negative electricity will be produced; in this case the rubber must be kept insulated, and the prime conductor and the earth connected. To prove that the quantity is equal, a metallic wire is placed between the two conductors, in which case no electricity can be obtained from either of them; if now two pith balls are suspended from the prime conductor, at a short distance from one another, and the machine is put in motion, the balls will repel each other, the divergence being caused by a mutual state of electricity. When the prime conductor is electrified, it induces an opposite state in any conducting substance that approaches it, the negative electricity of the body rushing to the positive electricity of the conductor. Hence a flash and snap is the result, and the equilibrium of the two different states of the electricity is restored. Upon the same principle of induction, depends the following experiment. If a person is supported upon a stool having glass legs, or a thick cake of resin or sulphur, and holding in his hand a chain proceeding from the prime conductor, he will become electrified, and another person standing upon the ground can draw sparks from him by presenting his knuckles to his body; and if spirits of wine are heated and presented to him in a metal spoon, upon touching the spirits with his finger, it will be instantly set on fire.

EXTRACT FROM AN ADDRESS DELIVERED AT THE ANNIVERSARY MEETING OF THE GEOLOGICAL SOCIETY OF LONDON.

By Leonard Horner, Esq., V.P.R.S., President of the Society.

The Carboniferous Series.

Although rocks of this age cover a great extent of country in European Russia, extending over a tract equally vast in horizontal extension with that occupied by the Devonian series, there are few places, except in the coal-field of the Donetz in the south, where the coal-seams are more than a few inches in thickness; and where they are thicker, they are so poor in quality as to be rarely worth working. The great coal-fields of England, France, Belgium, and America, have no well-marked equivalents there, nearly the whole of the coal-beds in the empire being, like those of Ireland and the coal-fields on the banks of the Tweed, included in the lower members of the system; which, with the sandstones, shales and marls, are the equivalents of our mountain limestone, as is proved by the identity of a large series of fossils. From a section of the works at Lissitchia-Balka, on the river Donetz, we learn, that in a depth of 900 feet there are twelve seams of coal, the united thickness of which amounts to thirty feet; they are associated with sandstones, grits, and shales; and eight beds of sandstone are intercalated (containing, from the uppermost to the lowest, marine shells), the united thickness of which is fifty feet, three of the beds of limestone resting directly on the coal. Many of the forms of Equisetacea, Calamites, Sigillariæ, and Ferns, are of the same species as those of the west of Europe; and the carboniferous fauna of Russia contains numerous forms identical with those in the same class of rocks in the British Isles.

A glance at the geological map which accompanies Mr Lyell's "Travels," shows the enormous development of the coal series in the territory of the United States, and that it occupies no inconsiderable space in Nova Scotia and New Brunswick. We learn from the report of Mr Logan, on the Geology of Canada, which I shall presently refer to, that a great coal-field covers nearly the whole of New Brunswick, a considerable part of Nova Scotia, Cape Breton Island, and the south-west corner of Newfoundland. The greater part of the carboniferous series in North America belongs to the upper portion, and not only abounds with numerous and thick beds of coal, but, on the western side of the Alleghanies especially, they are so little disturbed, and lie so nearly horizontal, that the coal is quite easy of access; and where the strata are intersected by rivers, it can be obtained with little trouble or expense. The great coalfield of Pennsylvania, Virginia, and Ohio, extends continuously from north-east to south-west for a distance of 720 miles, its breadth being in some places 180 miles.* That extending over parts of Illinois, Indiana, and Kentucky, is not much inferior in dimensions to the whole of England, and consists of horizontal strata, with numerous rich seams of bituminous coal. Another carboniferous deposit, 170 miles by 100, lies farther to the north, between Lakes Michigan and Huron. I may give the following as an example of the almost boundless resources of fuel which this country affords. At Brownsville, on the Ohio, there is a seam, ten feet thick, of good bituminous coal, commonly called the Pittsburg seam, which may be followed the whole way to Pittsburg, fifty miles distant. "The boundaries of this seam have been determined with considerable accuracy by the Professors Rogers in Pennsylvania, Virginia, and Ohio; and they have found the elliptical area which it occupies to be 225 miles in its longest diameter, while its maximum breadth is about 100 miles, giving a superficial extent of about 14,000 square miles."

Mr Lyell states that at Blossberg, in Pennsylvania, he was much struck with the surprising analogy of the coal-measures to those of Europe in mineral and fossil characters. The same grits or sandstones are found as those used for building near Edinburgh and Newcastle; similar black shales occur, often bituminous, with the leaves of ferns spread out as in a herbarium, the species being for the most part identical with British fossil plants; there are seams of good bituminous coal, some a few inches, others several yards in thickness, associated with beds and nodules of clay ironstone; and the whole series rests on a coarse grit and conglomerate, containing quartz pebbles, very like our millstone grit. The same similarity of mineral and fossil characters to European coal-measures is found to prevail throughout North America. That remarkable circumstance of the very general occurrence of a sandy clay abounding in Stigmariæ, beneath the seams of coal, observed in the Welsh and other coal-fields of Britain, is also found to prevail in those of North America. Mr Lyell saw numerous instances of this: thus, at Pottsville in Pennsylvania, there are thirteen seams of anthracitic coal (true bituminous coal supposed to be altered by metamorphic action, a subject to which I shall allude hereafter), several of them, from eight to ten feet thick, and in a vertical position: on the one side which had been the roof of the coal, consisting of shales, he observed numerous ferns with stems of Sigillaria, Lepidodendron, and Calamites; on the other side, that which had once been the floor, he found an underclay with numerous Stigmariæ, often several yards, and even in some cases as much as thirty feet long, with their leaves or rootlets attached.

Theories of the Formation of Coal.

It is scarcely possible to visit a coal-field, or to read the description of one, without being led to theorize on its mode of formation. The origin of coal has long been a subject of great difficulty, nor has any theory been yet advanced with which it has been possible to reconcile all the appearances which the coal-measures exhibit, all the variety of forms in which coal is found. Indeed, the more closely we examine the phenomena, the more do we feel the distance we are from a satisfactory explanation of them. According to some geologists, coal-seams and their accompanying strata are accumulations of land plants and stony detritus carried down by rivers into estuaries, and deposited in the sea, where the vegetable matter undergoes changes that convert it into coal. Others are of opinion that coal is the altered residuum of trees and smaller plants that have grown on the spot where we now find them; that the forests were submerged and covered by detrital matter, which was upraised to form a foundation and a soil for another forest to be in its turn submerged and converted into coal, and that thus the alternations which the vertical section of a coal-field exhibits are to be accounted for.

In the works of the last year to which I have chiefly referred, we find the former theory maintained by Sir R. Murchison as most generally applicable; Mr Lyell is more inclined to adopt the latter. Sir R. Murchison dwells upon the facts of the alternations of coal with limestones containing marine remains, which are so frequently met with in most countries where coal-fields prevail; and as a striking instance of this, he refers to the Donetz coal-field, which I have already alluded to. A remarkable example of a similar kind, occurring in Maryland, is mentioned by Mr Lyell.

* On the 17th of March I received a letter from Mr Lyell, dated the 16th of February, at Tuscaloosa in Alabama, containing a notice on the Alabama coal-field, and which was read at the Geological Society on the 25th of March. He states that he had been examining three coal-fields, the existence of which was unknown to him when he compiled his Map in 1844. They occur near Tuscaloosa, in the centre of Alabama, more than 100 miles farther south in a direct line than the southern limit which he had assigned to the Appalachian coal-field, and are situated on the Tombecbee, Great Warrior, and Cahawba rivers. That on the Great Warrior river has been found by Professor Brumby, of the University of Tuscaloosa, to be no less than ninety miles long from north-east to south-west, with a breadth of from thirty to forty miles. These coal-fields are portions of the great Appalachian coal-field, with the same mineral and palæontological characters. Mr. Lyell promises a more detailed account of his observations.

At Frostburg, a black shale, ten or twelve feet thick, full of marine shells, rests on a seam of coal about three feet thick, and 300 feet below the principal seam of coal in that place. The shells are referable to no less than seventeen species, and some of them are identical with, and almost all the rest have a near affinity to species found in the Glasgow and other coal-measures.

The theory which refers the coal to trees and plants which have grown on the spot where it now rests, is illustrated by Mr Lyell by observations he made in Nova Scotia, on the south shore of the Bay of Fundy, at a place called "The Joggins." He states that there is a range of perpendicular cliffs composed of regular coal-measures, inclined at an angle between 24 and 30 degrees, whose united thickness is between four and five miles. About nineteen seams of coal occur in the series, and they vary from two inches to four feet in thickness. The beds are quite undisturbed, save that they have been bodily moved from the horizontal position in which they must have been deposited to that inclination they now have. In these coal-beds, at more than ten distinct levels, are stems of trees, in positions at right angles to the planes of stratification, that is, which must have stood upright when the coal-measures were horizontal. No part of the original plant is preserved, except the bark, which forms a coating of bituminous coal, the interior being a solid cylinder of sand and clay, without traces of organic structure, as is usually the case with Sigillaria, and like the upright trees in the coal-measures cut through by the Bolton Railway. The trees, or rather the remains of stems of trees, broken off at different heights above the root, vary in height from six to twenty-five feet, and in diameter from fourteen inches to four feet. There are no appearances of roots, but some of the trees enlarge at the bottom. They rest upon, and appear to have grown in, the mass which now constitutes the coal-seams and under-lying shale, never intersecting a superior layer of coal, and never terminating downwards out of the coal or shale from which the stem rises. The underclay or shale often contains Stigmariæ. Here then, he states, are the remains of more than ten forests, which grew the one over the other, but at distant intervals, during which each, from the lowest upwards, was successively covered by layers of great thickness of clay and solid stone, the materials of which must have been arranged and consolidated under the surface of water, and the vegetation of every layer in which the upright trees are fixed must have grown on land.

The formation of coal-measures like the above, and of all others where there is evidence that the vegetable matter was not drifted to the place it now occupies, but must have grown on the spot, is then accounted for, by supposing that the land sank below the level of adjoining water; that gravel, sand, and mud, were washed down from the land that did not sink, and formed layers of clay and sandstone over the submerged forest, either in sufficient quantity to rise to the surface of the water and form land for the next forest, which was submerged in its turn, or that a contrary internal movement took place, which again raised the submerged land; and that for every seam of coal, one above the other, a similar series of changes must have taken place. It is to this oscillatory movement that Mr Lyell ascribes the formation of the above remarkable phenomena in the Bay of Fundy, and others of a like nature.

At first sight, both theories seem well founded, when applied to the particular coal-fields described; and it is possible that these eminent and experienced geologists may be of opinion that both are true, as applied to different situations. But I see great difficulties to the full acceptance of either, in many of the phenomena which, on a close examination, we find coal-fields generally present. As examples, I will call your attention to two sections that have very recently been published; the one a section of the western part of the South Welsh Coal-Field, included in the valuable series lately issued from the office of the Geological Survey of Great Britain, the work of W. E. Logan, Esq., a Fellow of this Society, so well known to us as an excellent observer, and as intimately acquainted with coal-fields, and who was formerly attached to that Survey; the other is entitled a "Section of the Nova Scotia Coal-Measures, as developed at the Joggins, on the Bay of Fundy, in descending order, from the neighbourhood of West Rugged Reef to Minudie, reduced to vertical thickness." It is also the work of Mr Logan, who is now employed by the Government of Canada to make a Geological Survey of that country, and is contained in his report to the late Governor, Sir Charles Metcalfe, and transmitted by the Governor to the Legislative Assembly. And here I may remark, in passing, that while we, as geologists, have to thank that provincial Government for commencing so useful an undertaking, we have also the satisfaction of feeling convinced that it will be prosecuted with vigour by the present governor, enrolled as one of our own body, and, as we know, an able and active geologist. This is a section of the same series of coal-measures so carefully examined and described by Mr Lyell, though with less minuteness of detail as to the lithological characters and dimensions of the several beds. The phenomena exhibited in the above sections are not peculiar to them; they are to a great extent common to all coal-fields, particularly in the higher parts of the carboniferous series.

Before giving the analyses I have made of these sections, I wish to call to your recollection that in both theories it is assumed that the deposition of the coal-measures took place *in the sea.* Mr Lyell speaks of the accumulations having taken place in a sea: he says, "It by no means follows that a sea four or five miles deep was filled up with sand and sediment; on the contrary, repeated subsidences may have enabled this enormous accumulation of strata to have taken place in a sea of moderate depth."

The example from South Wales is a vertical section, representing the beds as they are known to succeed each other in descending order, the dimensions being the thickness of each bed at right angles to the plane of stratification. The coal-measures rest upon carboniferous limestone, in an inclined and somewhat waved stratification; and although these measurements would vary in different places, from the swellings and thinnings-out which all strata exhibit more or less when traced to a distance, they are probably not far from the average amount over a large area.

1. From the top of the highest bed to the limestone, the sum of the measurements amount to nearly 7000 feet; that is, the beds must have been originally deposited over each other in horizontal or nearly horizontal stratification to that thickness.

2. Reckoning only the greater divisions, when a difference of mineral character takes place, there are, besides the coal-seams, 340 beds, from a few inches to 190 feet thick, without alteration of mineral composition; involving, in the latter cases, long periods without any change in the nature of the detritus washed into the water where the deposition was going on.

3. These beds consist of sandstones, arenaceous and argilliferous slates, and clays, alternating without any apparent order of succession: sometimes one sometimes another lying upon the coal; and occasionally, but not frequently, the shale upon the coal is said to be carbonaceous.

4. Interstratified with these beds are *eighty-four* seams of coal, from one inch to nine feet thick; the highest being covered by a series of beds of sandstone, &c., 200 feet thick; the lowest seam separated from the carboniferous limestone by 1340 feet of similar sandstones and shales, making the *coal-bearing* strata 5460 feet in thickness.

5. The seams of coal occur at very unequal distances; some are separated by a few inches only of shale or sandstone, others by as much as 360 feet.

6. There are twenty-three seams, occurring in succession, most of which are not distinguished by any term indicating quality; in two instances, one a three feet seam, they are said to be *bituminous*, and several seams are said to be *binding*, which means the same as *caking*, a quality which only richly-bituminous coals possess; the rest are merely called "Coal." These twenty-three seams, with their interstratified sandstones and shales, occupy 1840 feet.

7. Then succeed thirteen seams, in a space of 1000 feet, and nine of these are described as "*not bituminous*."

8. The thirty-seventh seam, in descending order, is said to be *anthracitic*, and fourteen seams below it are so designated: then come four seams merely called "Coal," and all very thin. Beneath the lowest of these, and separated by sixty feet of arenaceous shales and sandstones, comes a bed of coal, four feet six inches thick, called *Anthracite*, with five feet of underclay; beneath this are seven seams called *Anthracite*, and three more are intercalated called *anthracitic*.

9. Between the thirty-seventh seam, called Anthracitic, and the lowest of all, which is called Anthracite, three are twenty-two seams intercalated, without having any distinctive term affixed to them, most of them very thin; but about midway, three occur near together, without intermediate sandstones and shales, but separated by clay containing Stigmariæ, in the following manner:—

	Ft.	In.
Coal, ...	1	0
Underclay, ...	0	4
Coal, ...	4	0
Underclay, ...	8	0
Coal, ...	1	4
Underclay, ...	8	0

10. The seams of coal, whether termed merely "Coal," or bituminous, or anthracitic, or anthracite, have, with very few exceptions, underclays, and these, generally, but not uniformly, contain Stigmariæ. The two lowest beds of anthracite have underclays of five feet each, the third from the bottom has seven feet of underclay, each with Stigmariæ. The underclay is of variable thickness; in no part more than fourteen feet, and, except in a few instances, is always said to contain the *Stigmaria ficoides*.

11. There appears to be no relation between the thickness of the underclay with Stigmariæ, and that of the coal resting upon it. The thickest seam of coal, which is nine feet, rests on three feet of underclay; and there are instances of a seam of coal only an inch thick, with five feet of underclay stated to be *filled with Stigmariæ*.

12. A bed of clay, eight feet thick, wi h Stigmariæ, has no coal upon it, but a foot of carbonaceous shale; and above that forty feet of arenaceous shale, then four feet of clay with Stigmariæ, covered by three inches of coal, and that overlaid by twenty-five feet of argillaceous shale and sandstone.

13. In no case is any difference stated in the mineral character of the sandstones or shales either *over or under* the Anthracite seams, or of any other coal-seam.

The example from Nova Scotia is a vertical section, on the same plan as that in South Wales; and the coal-measures there also rest upon limestone, containing organic remains, "among which there is, in some abundance, a bivalve shell, which Mr Logan recognised as identical with *Producta Lyelli* of Windsor in Nova Scotia." This limestone at Windsor, Mr Lyell describes as a "lower carboniferous limestone." The total vertical thickness of the coal-measures is more than double that of the South Wales section, being 14,570 feet.

a. The number of distinct beds in the section, of which separate measurements are given, is 1114, from six inches to 138 feet thick, without change in mineral composition.

b. These beds consist of quartzose sandstones, grits and conglomerates, and of arenaceous and argillaceous shales, all of various shades of red, grey, and green, without any apparent order of succession, sometimes one, sometimes another lying upon the coal, and occasionally a carbonaceous shale is associated and intermixed with the coal-seams.

c. Interstratified with these beds are *seventy-six* seams of coal, from an inch to two feet thick, the far greater proportion very thin. The aggregate thickness of the seventy-six seams is only forty-four feet, and there is about the same aggregate thickness of carbonaceous shale. The highest seam is covered by a series of beds of sandstones, conglomerates and shales, 2274 feet thick. Beneath the lowest seam of coal there are 2800 feet of sandstones and shales of the same nature as those above, but having numerous beds of grey concretionary limestone intercalated. Thus the *coal-bearing* strata have a thickness of about 9500 feet.

d. There are no terms attached to the word "Coal," indicating any change of quality throughout the section. Some of the seams are called "Coaly clay," others "Carbonaceous shale," mixed with the coal. The seams occur at very unequal distances; from a few inches apart to more than 1200 feet.

e. As in the South Wales section, the coal-seams usually rest on beds containing *Stigmariæ*, but, in a great proportion of instances, these occur not in clay but in sandstone and arenaceous shale. This under bed is from a foot to twenty-seven feet in thickness; in one place an understone with *Stigmariæ* ten feet thick has a seam of coal over it only an inch thick.

f. Between the sixty-seventh and sixty-eighth coal-seams, the former with associated carbonaceous shale only fourteen inches thick, there are 170 beds of sandstone and argillaceous shale, from six inches to 132 feet thick, their aggregate thickness being 2620 feet, and the sixty-eighth coal-seam is only called coaly clay, two inches thick, with an underclay containing *Stigmaria* leaves of six feet.

g. In the 2274 feet of sandstones, &c., lying above the highest seam of coal, fragments of plants are seen in several of the beds; they first occur in a bed of sandstone 218 feet from the top, and the plants are converted into coal; they are often called "drift plants," and stated to be "coated with coal." In one bed there are "carbonized drift plants of large diameter," say one foot, the stems lying prostrate; and 1520 feet below this, there is a sandstone "fit for grindstones, with a few *Calamites* nearly at right angles to the plane of the beds, as if *in situ*, but forced over at the top;" this sandstone rests on a black carbonaceous shale two feet thick, but it is not stated whether the Calamites are fixed in this carbonaceous stratum. Between this last and the first seam of coal, which is only one inch thick, there are three feet of a "greenish-grey sandstone with *Stigmaria ficoids*," succeeded by two feet of "grey argillaceous shale, with impressions of *ferns* and other plants."

Between the seventy-fifth seam, half an inch, and the seventy-sixth, two inches thick, are eighty-four beds of sandstone from a foot to 117 feet thick, together 1223 feet; and twenty of these beds, all called greenish-grey sandstone, are said to contain carbonized drift plants; and in one of these beds there is said to be "a vast confused collection of carbonized drift plants; one, lying prostrate, measured twenty-five feet in length, and about 1 foot in diameter at the small end." So likewise in the 2800 feet of sandstones, &c., which are beneath the seventy-sixth or lowest seam of coal, ten of the beds are said to contain carbonized drift plants.

h. At a distance of 4400 feet from the surface there occurs a "bituminous limestone with shells and fish-scales," four feet thick, and lower down, in the succeeding 200 feet, there are eighteen beds of similar bituminous limestone, one of them only half an inch thick, eleven of them under six inches, and the thickest two feet. Neither the shells nor the nature of the fish-scales are described, but that these are freshwater limestones may be inferred from this, that several of them are mixed with Stigmariæ and other plants; thus associated with the twenty-eighth seam of coal is a "bituminous limestone and carbonaceous shale in alternate layers of one to three inches, with *plants*, shells and fish-scales;" under the thirty-first, with Stigmariæ, shells and fish-scales;" along with the thirty-sixth, "black bituminous limestone with branches and leaves of *Stigmariæ* well-marked, and very minute-shells;" under the forty-fourth, "with *Stigmariæ* branches and leaves, fragments of other plants, and minute shells;" Mr Lyell states, that he observed "not far above the uppermost coal-seams with vertical trees, two strata, *perhaps of freshwater or estuary origin*, composed of black calcareo-bituminous shale, chiefly made up of compressed shells, of two species of *Modoila*, and two kinds of *Cypris*." It is possible, therefore, that the "minute shells" of Mr Logan are *Cypris*. Beneath the lowest seam of coal are intercalated fourteen beds of what is called a "Concretionary limestone," and "Limestone in concretionary nodules," from one to three feet thick, one of as much as eight feet, and in one instance the limestone is said to contain carbonized drift plants.

i. Several instances are given of stems of plants standing perpendicular to the plane of stratification; the first is 2160 feet from the top of the uppermost bed.

α. Calamites "as if *in situ*."

β. Lower down, 570 feet below *a*, two upright stems of Calamites, two inches in diameter, coated with coal, start from the top of a dark-grey argillaceous shale, and penetrate into a grey shale with sandstone above. The length of the stems is not given.

γ. Forty feet below is a foot of sandstone and then a foot of shale, and "in this shale, and running into the sandstone above, is a Calamite at an angle of 45°: it appears to start from a coal-seam below, an inch thick.

δ. Beneath this, 640 feet, a seam of coal three inches thick occurs, and from it "there springs up an erect *Sigillaria*, eighteen inches in diameter, and it penetrates the shale and sandstone above it, five feet of the plant being visible." Underneath the coal is "a grey sandstone with *Stigmaria ficoides* (*underclay*)."

ε. The next instance given is 1038 feet lower down, where, from a grey argillaceous shale, rises an upright *Sigillaria*, one foot in diameter, penetrating to a height of two feet into argillaceous shale above. There are sixteen feet of sandstone and shale below this, *Sigillaria*, and *without Stigmariæ*.

ζ. The next is 270 feet lower, where, from an argillaceous shale, "springs an upright *Sigillaria* of one foot in diameter; the lower part commences to spread." There are seven feet of argillaceous shales, with ironstone balls, beneath this *Sigillaria*, *without Stigmariæ*.

η. The next is 228 feet lower, where, from a "grey, crumbly, argillaceous shale, like underclay, but no *Stigmariæ* visible, spring several upright Calamites, three of them in the distance of two feet, and eight more, the whole eleven in the distance of twenty feet."

θ. The next, 137 feet lower, in sandstone, are upright Calamites, three in the space of a foot.

ι. From a carbonaceous shale, a foot thick, sixty-two feet lower, "spring up erect Calamites, penetrating an arenaceous shale above two feet; and there are seven in the space of eight feet."

κ. The next is 254 feet lower, where, from an argillaceous shale, springs an upright *Sigillaria*, four inches in diameter; five feet of it are seen in a sandstone above. Argillaceous and carbonaceous shale beneath, six feet thick, does *not* contain *Stigmariæ*.

λ. From a grey argillaceous shale, twenty-two feet lower down, springs an upright *Sigillaria*. Its roots spread out into the shale, which is ten feet thick, and does *not* contain *Stigmariæ*; but *over* it lies a grey, crumbly, argillo-arenaceous shale or sandstone *with Stigmariæ*, in which six feet of the stem are visible. From the root of the plant proceeds a *Stigmaria* branch, which at first sight had much the appearance of the Sigillaria, but close inspection showed that the two, although touching, were distinct.

μ. The next is 108 feet lower, where, from a grey argillaceous shale, "springs an upright *Sigillaria*, eighteen inches in diameter, penetrating an incumbent sandstone." Fourteen feet of argillaceous shale and sandstone beneath do *not* contain *Stigmariæ*.

ν. The next is 133 feet lower, where, from a thin seam of coal with carbonaceous shale beneath, "rises an upright *Sigillaria*; the roots spread on the top of the coal; the plant is a foot in diameter, and only one foot of the length is visible."

ξ. The next is 160 feet lower, where, from a red argillaceous shale springs an upright *Sigillaria*. Two feet of the length is seen, but it is cut clean off at the top and at the bottom by the measures which pass both without disturbance. No *Stigmariæ* occur for many yards below.

ο. The next is 101 feet lower, where, from a grey argillaceous shale, six feet thick, without *Stigmariæ*, starts an upright *Sigillaria*, four inches in diameter; it is planted two feet in the shale, and penetrates the sandstone above, being four feet in length altogether.

π. The next is 362 feet lower, where, from a red and dark grey variegated shale, twenty-eight feet thick, with small balls of ironstone and *Stigmariæ*, arise two upright *Sigillariæ*. The roots of these spread out just on the top of the bed, and two feet of the plant are visible. The roots of the other spread out likewise, but they sink deeper into the shale by two feet, and the plant penetrates farther into the superincumbent sandstone.

ζ. The next distinct instance is 490 feet lower, where, from a grey argillaceous shale, several upright *Calamites*, from half an inch to four inches in diameter, penetrate an incumbent grey arenaceous and argillaceous shale, containing prostrate carbonized plants. The roots of a Calamite three inches in diameter, spread on the top of the shale underneath; and twenty-one more Calamites are visible along the bank in the space of twenty yards.

This is the last instance stated of stems of plants found in the strata perpendicular to the plane of stratification: the seventeen instances thus occurring in a vertical thickness of 4515 feet.

Throughout the whole 7000 feet in the South Wales section, and, if the limestones are, as is most probable, of fresh water origin, also throughout the 14,570 feet in the Nova Scotia section, there appears to be no trace of any substance of a marine character; and from anything exhibited in the composition of the beds, all might have been deposited in fresh water. It seems infinitely improbable, had the deposition taken place in a sea, that a series of accumulations of this description, implying, be it observed, a vast duration of time, with different depths and different qualities of sea-bottoms, should have taken place without a trace being discoverable, either upon the surface of the submerged layers of vegetable matter, or in any part of the clays and sandstones that lie upon them, of a marine animal or plant. It seems no less improbable that, in a sea skirting a shore, there should be such an absence of agitation throughout so vast a space of time, as to allow a tranquil deposit of layers of fine detritus over a wide area, a spreading out of the leaves of delicate plants in layers of clay and sand, like the specimens in a herbarium, and a gradual and insensible passage, in many instances, from one bed into another. Great as the North American lakes are, I am not prepared to say that grave objections may not be urged against the probable existence of such vast bodies of fresh water as would be of sufficient extent and depth to receive the beds of many coal-fields; but the absence of marine remains throughout vast depths of strata in coal-fields is a remarkable fact, well deserving of the most careful investigation.

That the terrestrial vegetable matter from which coal has been formed has in very many instances been deposited in the sea, is unquestionable, from their alternations with limestones containing marine remains. Such deposits and alternations in an estuary at the mouth of a great river are conceivable, but whether such enormous beds of limestone, with the corals and molluscs which they contain, could be formed in an estuary, may admit of doubt. But it is not so easy to conceive the very distinct separation of the coal and the stony matter, if formed of drifted materials brought into the bay by a river. It has been said that the vegetable matter is brought down at intervals, in freshets, in masses matted together, like the rafts in the Mississippi. But there could not be masses of matted vegetable matter of uniform thickness 14,000 square miles in extent, like the Brownsville bed on the Ohio (the Pittsburg seam mentioned in page 170); and freshets bring down gravel, sand, and mud, as well as plants and trees. They must occur several times a year in every river; but many years must have elapsed during the gradual deposit of the sandstones and shales that separate the seams of coal. Humboldt tells us (*Kosmos*, p. 295), that, in the forest lands of the temperate zone, the carbon contained in the trees on a given surface would not, on an average of a hundred years, form a layer over that surface more than seven lines in thickness. If this be a well-ascertained fact, what an enormous accumulation of vegetable matter must be required to form a coal seam of even moderate dimensions! It is extremely improbable that the vegetable matter brought down by rivers could fall to the bottom of the sea in clear unmixed layers; it would form a confused mass with stones, sand, and mud. Again, how difficult to conceive, how extremely improbable in such circumstances, is the preservation of delicate plants, spread out with the most perfect arrangement of their parts, uninjured by the rude action of rapid streams and currents carrying gravel and sand and branches and trunks of trees.

In the theory which accounts for the formation of beds of coal, by supposing that they are the remains of trees and other plants that grew on the spot where the coal now exists, that the land was submerged to admit of the covering of sandstones or shales being deposited, and again elevated, so that the sandstones or shales might become the subsoil of a new growth, to be again submerged, and this process repeated as often as there are seams of coal in the series—these are demands on our assent of a most startling kind. In the sections above examined, we have eighty-four seams of coal in the one, and seventy-six in the other. In the Saarbruck coal-field there are 120 seams, without taking into account the thinnest seams, those less than a foot thick.* The materials of each of these seams, however thin (and there are some not an inch thick, lying upon and covered by great depths of sandstone and shales), must, according to this theory, have grown on land, and the covering of each must have been deposited under water. There must thus have been an equal number of successive upward and downward movements, and these so gentle, such soft heavings, as not to break the continuity or disturb the parallelism of horizontal lines spread over hundreds of square miles; and the movements must, moreover, have been so nicely adjusted, that they should always be downward when a layer of vegetable matter was to be covered up; and in the upward movements, the motion must always have ceased so soon as the last layers of sand or shale had reached the surface, to be immediately covered by the fresh vegetable growth; for, otherwise, we should have found evidence, in the series of successive deposits, of some being furrowed, broken up, or covered with pebbles or other detrital matter, of land long exposed to the waves breaking on a shore, and to meteoric agencies. These conditions, which seem to be inseparable from the theory in question, it would be difficult to find any thing analogous to in any other case of changes in the relative level of sea and land with which we are acquainted.

That some seams of coal were formed of vegetable matter that grew on the spot where the coal now exists, seems to be proved in several cases (such, for instance, as that of the Bolton railway section) beyond dispute; and that some seams afford proofs of having been formed by drifted vegetable matter may be true. The coal-seams, and the beds associated with them, could be formed in no other way than under water; and the accumulation of the vegetable matter near the surface of it, and a very gradual submergence of the land, arrested at unequal intervals, appear to be the conditions most reconcileable with the phenomena. This implies, however, a deposition of the alternating sandstones and shales in very shallow water; and as we often find these rocks in regular thin stratification, forming the immediate bottom of coal-seams, the question arises, could such a laminated arrangement of detrital matter take place in water so shallow as is here supposed?

It is held by some geologists, that *Stigmariæ* are the roots of *Sigillariæ*, and that the stems of the latter contributed largely to the formation of coal. We should therefore expect to find, that where there is the greatest accumulation of *Stigmariæ* there should be the thickest seams of coal: this is not only not the case in the above sections, but sometimes there is no coal at all (11, 12, *e*, *f*, *g*). In a bed of sandstone, 190 feet thick, in the South Wales section, and at a depth within it of sixty feet, there is a seam of coal, four inches thick, without underclay and without

* Humboldt's Kosmos, p. 295.

Stigmariæ. Then again, in the Nova Scotia section, we find stems of *Sigillariæ*, standing at right angles to the plane of stratification, resting on shales that do not contain any *Stigmariæ* (ι, ζ, κ, λ, μ). Is this a proof that the stems are here, though apparently, really not in the place where they grew? or is it a proof that *Stigmariæ* are not the roots of *Sigillariæ*?

Several instances of upright stems given in the Nova Scotia section by Mr Logan, can hardly be considered as occupying the spot where they grew, certainly not that (ξ) where it is cut clean off at the bottom. It is remarkable, that, in the instances of upright stems described by Mr Lyell and Mr Logan, if occupying the spot where they grew, roots should so seldom be connected with them. Of all parts of the tree, none, we should expect, would be more likely to be preserved; being protected by their covering of soil from causes of destruction to which the stems were evidently exposed, as we find them so generally cut off at a short distance above their bases.

The whole subject of the theory of coal, whether we consider its mode of deposition, the plants out of which it has been formed, or the various changes which the vegetable matter has undergone, to convert it into lignite, jet, common coal, cannel coal, blind coal, and anthracite. Two or more of these varieties often occurring in the same coal-field, is extremely obscure, and presents a wide and interesting field for future investigation. Before concluding this part of my subject, into which I shall probably be thought to have entered at disproportionate length, I would call your attention to some difficulties which the South Welch section offers to the commonly-received and, I believe, well-founded opinion, that anthracite is bituminous coal, the volatile parts of which have been driven off by heat acting gradually from below; for we see (8 and 9) that thin seams of common coal are interstratified with anthracitic seams and with anthracite. Neither do we find any signs of metamorphic action in the underclay in immediate contact with the coal, nor in the strata that lie between two seams of anthracite. We must look to the chemist to explain all this, as well as for enlightenment on the formation of the different qualities of coal; but we must be contented to receive from him only indications and resemblances; for we must never forget, that, in our experiments, we can never have the volume of materials, the amount of pressure, and above all, the duration of time with which Nature has worked; and each of these, singly and combined, must have had an important influence in modifying the results.

THE UPAS TREE.

There are few who have not heard of the dreadful Upas or poison-tree of Java. Clayer and Spielman described it upwards of a century ago, and assert that the land for fifty miles round it is desolate and barren, and covered with thousands of ghastly skeletons, the sole remnants of its direful effects. For the poison, they state, there is no antidote; it flows from the tree like a milky juice, and one drop of it touching the skin produces instant stiffness of every limb, and immediate death. Even its exhalations, according to the same authorities, are fatal, and it cannot be approached except in the direction of the wind, and then its poison, which is highly precious, is collected at the end of long bamboo canes, armed with a pointed tube to receive it when plunged into the bark.

More recent travellers have confirmed, in a great measure, the statements of Clayer and Spielman. Rumphius, for instance, after describing the tree with something like botanical accuracy, adds, that it grows in the island of Celebes, and that all around it is desert, every living thing being destroyed by its malign influence. The account given by Foersch, a Dutch physician, is still more recent and circumstantial. After informing us that all he is going to say is perfectly true, he proceeds to give a minutely detailed account of the manner in which the Upas poison is obtained. He informs us, that criminals under sentence of death are permitted to choose whether they will suffer by the public executioner, or accept of a pardon on the condition of procuring a small boxful of the Upas poison. Of the two evils, they of course prefer the latter, which affords them a slight chance of escape, and if fortunate enough to return with the invaluable and terrific substance, they are not only relieved from all fear of punishment for old offences, but are richly rewarded as having done good service to the state. To prepare them for their departure, on the forlorn errand, they are first sent to the dwelling of a priest, who lives at a safe distance from the spot, and whose duty it is to afford assistance, both spiritual and temporal, to such malefactors as undertake the dreadful expedition. At stated periods of the year, bands of prisoners, accompanied by their disconsolate and weeping families, arrive at this holy man's residence, and remain with him a few days, to receive their instructions, and such good advice as may be of service to them, should circumstances prove favourable during the journey. They are, of course, strongly urged not to set out until the wind blows in such a direction as to waft from them the noxious emanations of the Upas, and on their departure he covers their heads and faces with leathern hoods, having two glass eyes, and supplies each with a thick pair of gloves of the same material, for the protection of their hands, and a small silver, ivory, or tortoise-shell, poison-box, which it is their business to return full. He then accompanies them to the summit of a hill about two miles distant, which commands an extensive view in the dismal direction. He there describes to them the awful spot where the treasure is to be found, as minutely as one can be expected to describe what he has not seen; urges upon them to travel at the greatest speed, and to follow the course of a little stream, which, at the distance of thirty miles from this point, flows close past the tree. Then giving the pilgrims his fervent blessing, he sits down to watch their descent into the fatal region. "Should the wind at the commencement of the journey blow in the direction of the Upas, until the first thirty miles are travelled over, then they are usually safe; but should the wind blow in their faces, and waft towards them the deadly poison, they surely die."

The worthy old priest informed our veracious traveller, that during the thirty years he had held the enviable situation, he had sent off not less than seven hundred malefactors, and of all these only seventy-two returned. He confirmed this statement by reference to a register which he had kept, containing the names of all the criminals who had undertaken the expedition, and the crimes for which they had been condemned. Our traveller further assures his readers, that he witnessed several of these expeditions, and entreated several of the culprits to bring him even the smallest branch of the tree; but two withered leaves were the only specimens he could obtain, and these were brought to him by a solitary wretch who had escaped the fate of his companions. This fortunate sinner described the tree as growing on the borders of the rivulet mentioned by the priest, being of a moderate height and surrounded by a cluster of young ones. The ground around the clump was arid sand, strewed with bleached skeletons of human and other victims, and he ascertained by some means which the Dutchman does not record, that no living creature could exist within fifteen miles of the pestiferous spot. In all the district the streams are destitute of fish, and the birds that attempt to fly over it fall to the ground, and add their bones to the general signs of desolation. It was this account which Dr Darwin had before him when he wrote the following beautiful lines of his poem, called the Botanic Garden, or the Loves of Plants;—

> Where seas of gold with gay reflection smile,
> Round the green coasts of Java's palmy isle.
> A spacious plain extends its upland scene,
> Rocks rise on rocks, and fountains gush between;
> Soft zephyrs blow, eternal summers rain,
> And showers prolific bless the soil in vain.
> No spicy nutmeg scents the vernal gales,
> Nor towering plantain shades the mid-day vales,
> No grassy mantle hides the sable hills,
> No flowering chaplet crowns the trickling rills,
> Nor tufted moss, nor feathery lichen creeps,
> Nor russet tapestry o'er the crumbling steeps,
> No step retreating on the sand impressed,
> Invites the visit of a second guest.
> No refluent fin the unpeopled stream divides.
> No revolant pinion cleaves the airy tides,
> Nor handed moles, nor beaked worm return
> That mining pass the irremedial bourne;
> Fierce in dread silence on the blasted heath,
> Fell Upas sits—the hydra tree of death.
> Lo! from one root the envenomed soil below
> A thousand vegetative serpents grow:
> In shining rays, the scaly monster spreads
> O'er ten square leagues, his far diverging heads,
> Or in the trunk entwists his tangled form,
> Looks o'er the clouds and hisses in the storm;
> Steeped in fell poison, as his sharp teeth part,
> A thousand tongues in quick vibration dart;
> Snatch the proud eagle towering o'er the heath,
> Or pounce the lion as he stalks beneath,
> Or strew, as marshalled hosts contend in vain,
> With human skeletons the whitened plain;
> Chained at his root two scion demons dwell,
> Breathe the faint hiss, or try the shriller yell,
> Rise fluttering in the air on callow wings,
> And aim at insect prey their little stings.

Of the dreadful activity of the Upas-poison, the same veracious Dutchman gives us many illustrations, and we are led to understand that he might have adduced many thousands. Among the most important which he brings forward, and that on which he is most eloquent—meaning Dutch eloquence—is the execution of fourteen of the emperor's wives for the crime of infidelity. These unfortunate ladies were inoculated in the bosom, with the point of a Malabar dagger (*kritz*) dipped in the juice of the Upas, and in sixteen minutes they had all ceased to live. Foersch after this narration goes on to prove that the general unhealthiness of Java is owing to the presence of this solitary tree, and that it is in short the very bane of the whole island. Its emanations, he shows, are pestiferous over the length and breadth of the land, and it affords facilities for secret murder, of which the natives are but too ready to avail themselves. Almost all of them of quality carry poisoned daggers which they frequently use with fatal effect. It is not surmised that a dagger might be so used without poison; he also assures us that the Dutch inhabitants of the island never travel without carrying fish with them, which they invariably take care to throw into the water before they presume to drink of it. If the fish live, all is well; if they die, the water is poisoned. Finally, he relates a tradition which according to him, is current in Java, relative to the origin of the tree. The substance of it is this—that part of the island which is now desolate, was once fertile and densely peopled, but the people became in process of time so grossly wicked, that Mahomet, as a punishment for their iniquities, caused the Upas to spring up, and its poisonous emanations in one day destroyed the whole race and every living thing within its fatal influence.

Now, there is perhaps no fiction in which there is not some truth, and the account of Foersch is not an exception. It is true that in Java there is a poisonous valley, and it is also true that in the same island there grows a poisonous tree, called *upas* or *oupas;* but these have no relation to each other. The poison valley, or Valley of Death, as it is called, is simply a natural excavation of about half-a-mile wide, and filled with carbonic acid gas, like the celebrated Grotto del Cane, or Dog-Grotto, near Naples; and the Upas, so far from creating desolation and death for many miles around it, is a tree which grows in the most fertile situations, and is surrounded by all the luxurious vegetation of an eastern clime. It is common in the forests—climbing plants twine round its stem, birds build their nests among its leafy branches, and the beasts of prey come to sleep in its widely spreading shade. The tree, moreover, is common to all the Molucca Islands, and, indeed, is found throughout all the Indian Archipelago, where it is known by the names of *Bohou Upas*, *Boa Upas*, and *Pohou antiar.* In Java there are two varieties, called *Upas antiar*, and *Upas tieute.* The last yields the true Upas-poison, or *Ipo.* The tree, according to Deschamps, frequently rises to the height of thirty or forty feet, and bears some resemblance to our elm. When one of its branches is broken off, or its bark is incised, a milky juice exudes, which becomes inspissated in the atmosphere. M. Leschenault, during his residence in Java, procured several specimens of this poisonous substance, as made there and in the neighbouring islands. It is usually prepared for fatal use by admixture of some foreign ingredient to quicken its deadly effect. The Malays add to it chiefly galanga and garlic, but the mountaineers of the interior of Borneo, called *Orang-Daias*, keep its preparation a profound secret. They carry it about with them, wrapped up in palm-leaves, to poison the spear-pointed heads of their hunting arrows as occasion may require. Their war-arrows are likewise impregnated with the same substance, but in a peculiar way. These bear a shark's tooth fixed in a brass socket, and merely attached to the shaft by the gum resin of the Upas. When the arrow strikes, the barbed point remains rankling in the wound it inflicts, and, the gum dissolving, speedily brings on death. M. Leschenault tried several of these arrows on dogs and other animals, and they all expired shortly after in horrible convulsions. This confirms the relation of Rumphius, who states, that the Dutch, in their wars with the Javanese, were obliged to wear thick buff cuirasses to protect them against their poisoned missiles, the wounds of which were invariably fatal.

Dr Horsfield furnishes the latest account of the Upas. He was in Java during its occupation by our troops, and had considerable opportunity of acquiring correct information. He informs us that Foersch's account is undoubtedly a fabrication, but states that there does exist a tree, called *Anchar*, from which the natives prepare a fatal poison. According to him, it belongs to the class *Monœcia* of Linné. "The male and female flowers are produced on the same branch at no great distance from each other. The seed-vessel is an oblong drupe, covered with a calyx; the seed, an ovate nut with cells. The top of the stem sends off a few stout branches, which, spreading nearly horizontally with several irregular curves, divide into smaller branches, and form a hemispherical (not very regular) crown. The stem is cylindrical, perpendicular, and rises completely naked to the height of sixty, or seventy, and even eighty feet. Near the surface of the ground, it spreads obliquely, like many of our forest trees. The bark is whitish, slightly bursting into longitudinal furrows. Near the ground, this bark is, in old trees, more than half an inch thick; and, when wounded, yields copiously the milky juice from which the poison is prepared. This juice is yellowish, frothy, and becomes brown when exposed to the air." The Doctor further informs us, that the juice is fatal to animals—kills dogs in an hour, mice in ten minutes, cats in fifteen, monkeys in seven, and that a buffalo, subjected to the experiment, was two hours and ten minutes in dying.

Delile and Magendie made a very extensive series of experiments with the specimens of the poison brought home by Leschenault, and they found it to act with more or less energy according to the age and size of the individual, and the quantity of the Upas. A grain and a half inoculated into a young dog destroyed it in four minutes, only producing one convulsive fit. Half a grain killed a dog of fourteen pounds weight in about two hours, during which the animal experienced violent convulsions. A few drops of diluted Upas were injected into the chest of a dog of twenty-eight pounds; jawlock immediately ensued, and the animal died in a minute and a half. Eight drops of the same substance were injected into the jugular vein of a horse, and the effects were likewise immediate jawlock and speedy death. These, and other cruel experiments of the same sort, show not only the power of this poison, but also that its intensity is not impaired in any ordinary period of time, for the poison used in these trials of its strength had been kept for upwards of seven years.

The poison of the Upas is evidently of the narcotic kind, and, of course, no antidote is known for it when taken into the circulation. The Javanese consider that sea-salt is the best antidote, but Delile found it totally useless in that respect. Some of that gentleman's experiments, moreover, led him to think that the poison produces death by asphyxia, and that the means employed to restore suspended animation, in persons supposed to be drowned, are the most likely to save the life of an individual in any way poisoned with this substance.

The juice of the Upas is not the only substance which savage tribes employ to give a deadly effect to their missiles. The Indian of Guiana dips his arrows into *Curara*, which occasions speedy death and decomposition of the lungs. This poisonous juice is obtained, according to Humboldt, from the bark of a tree called *Vejuco de Mavacure;* it is inspissated over a slow fire, and then mixed with a gum drawn from the *Kiracagnero.* The *Wourali* poison, used by the Macoushi Indians, is equally celebrated. Mr Waterton has supplied us with a minute account of its preparation, which, during his travels in South America, he had every means of learning. According to this gentleman, the *Wourali* is a species of vine which grows in the dense tropical forests, and it is from this that the poison takes its name as being the chief ingredient in it. The preparation is attended with much ceremony. The Indian sets out alone in search of wourali, and when he has procured enough of this, he digs up a root of a very bitter taste, ties them together, and then looks about for two kinds of bulbous plants which contain a green and glutinous juice. He then fills a little vessel, which he carries on his back, with the stalks of these, and, lastly, ranges up and down till he discovers two species of ants; one of them is very large and black, and so venomous that its long sting produces a fever; the other is a little red ant, which stings like a nettle. To these he adds a quantity of the strongest pepper, and the pounded fangs of the Labarri and Connacouchi snakes, which he usually has in store; for when he kills a snake, he generally extracts the fangs and keeps them by him. Having thus found the necessary ingredients, he scrapes the *Wourali* vine and bitter root into shavings, and puts them into a kind of colander made of leaves; this he holds over an earthen pot, and puts water on the shavings; the liquor which comes through has the appearance of coffee. When a sufficient quantity has been procured, the shavings are

thrown aside. He then bruises the bulbous stalks, and squeezes a proportionate quantity of their juice through his hands into the pot. Lastly, the snakes' fangs, ants, and pepper, are bruised and thrown into it. It is then placed on a slow fire, and, as it boils, more of the juice of the wourali is added, according as it may be found necessary, till it is reduced to a thick scum of a deep brown colour, when a few arrows are poisoned with it to try its strength. If it answers expectation, it is poured into a calabash, which is carefully covered over with a couple of leaves, and over them a piece of deer's skin is tied. It is carefully kept dry, and occasionally suspended over the fire to counteract the effects of any dampness it may have imbibed. The poison has the most powerful action on animal life; but it destroys life so gently that the victim appears to feel no pain. In this respect it seems to differ very much from the Upas poison, which produces the most horrid convulsions.

A similar degree of mystery seems to be practised in the preparation of both; but the snakes' fangs and ants are perhaps peculiar to the American. All tribes, indeed, seem anxious to confine the secret of the preparation to their elders, in the belief that there is a supernatural agency required to give the drug its full activity, and this can only be expected when the ceremonies are gone through with becoming decorum.

MANUFACTURE AND COUPLING OF MALLEABLE IRON PIPES.

BY M. SOREL.

M. SOREL's processes, together with the different machines which belong to them, embrace quite a manufacture in themselves. The original patent and the numerous additions made to it, afford materials for a detailed description; but without proceeding to such extensive details, we shall endeavour, with the aid of the annexed figures, to explain the different parts of the manufacture.

Riveted Pipes.—Fig. 1 is a longitudinal section of the important part of a double-cylinder machine for making riveted pipes. This machine, with some slight modifications, may be employed to clasp the pipes.

Fig. 1.

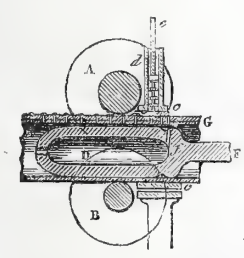


Fig. 2.

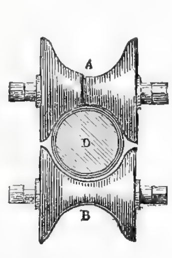


Fig. 2 represents the machine, seen in the direction of the length of the cylinders, or in cross section.

Instead of a single inferior cylinder, B, two may be employed, placed at the same height, and between which would be brought to bear the action or pressure of the upper cylinder, A, for riveting the bolts. The neck of the cylinder is roughened or radiated, so as not to slide on the rivets.

A fixed mandril, D, passes through the hollow of the pipe.

The pipe, D, to be riveted is first pierced at its two edges, while the sheet of iron is still spread out; it is then rolled in the form of a pipe between the necks of the cylinders or otherwise, and, by passing the pipe into a tube, G, placed in front of the cylinders, it is taken up between the latter.

The rivets, placed in a tube or kind of hopper, *d*, fall one by one into the holes as they present themselves, and are drawn in and crushed between the cylinder, A, and the mandril. To overcome any small resistance presented, a constant pressure is exerted on the rivets in the tube by the intervention of a rod, *e*.

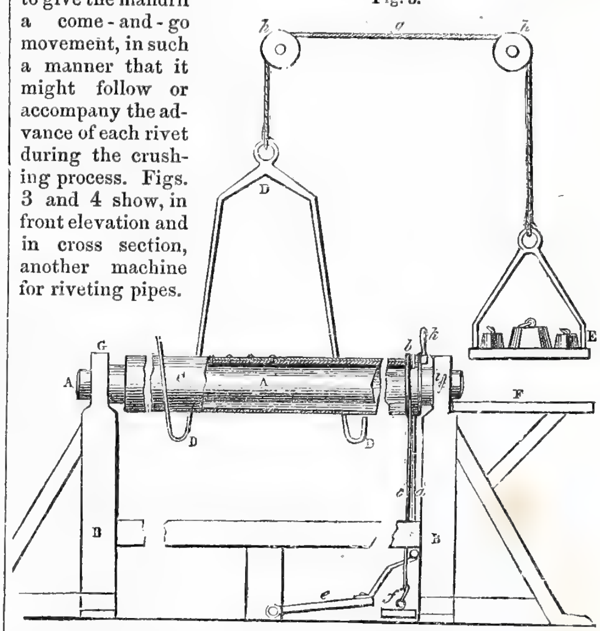
Rivets with heads may be replaced by bits of stout iron wire, which will sink as far as the mandril, their length being regulated by the latter.

Instead of piercing the sheet of iron beforehand, it may be pierced as the work proceeds, by means of a lever-piercing machine. For this purpose the mandril, D, should be hollow, as in fig. 1, to receive and convey outward the matter detached from the pipe in forming the holes, and which would fall into the mandril by the hole, *f*.

An upright, or bracket, is opposed to the action of the piercer. In this latter arrangement the action of the cylinders would be intermitted, and would of course be interrupted while the piercing machine was in operation.

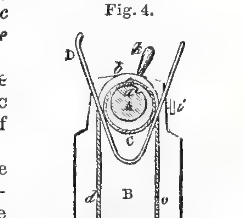
To prevent the interior head of the rivet from being thrown entirely to one side by the rubbing of the mandril, the inventor proposes to give the mandril a come-and-go movement, in such a manner that it might follow or accompany the advance of each rivet during the crushing process. Figs. 3 and 4 show, in front elevation and in cross section, another machine for riveting pipes.

Fig. 3.



A is a long iron or steel mandril, a little flattened on one side, and of a less diameter than the pipe to be riveted. A groove, *a*, runs along the whole length of this mandril, and at its extremity it carries a pulley, *b*, to which are attached two cords, *c* and *d*, acted on by the pedals, *e* and *f*.

Fig. 4.



B is the frame which supports the mandril, A, in two cushions, and C the pipe submitted to the action of the machine.

A crotch, D, suspended to the cord, *g*, which passes over the pulleys, *h*, supports in equilibrium the pipe, C, by means of weights placed on the plate, E, which, when not in operation, rests on the shelf, F.

The pipe, being previously pierced, bent, and held by two or three rivets, is fitted on the mandril, which is raised at the end, G. The crotches, D, are then passed under the pipe, and the latter is balanced in this position.

Pressure is now applied on the pedal, *e*, which raises the groove, *a*, of the mandril, so as to correspond in this position to the holes of the pipe. The rivets are inserted with blows from a hammer; then, with one hand, the pipe is slightly raised; the pedal, *f*, is then pressed to bring the flat part of the mandril under the rivets, and the mandril is arrested in this position by a pin, *i*. Lastly, the crushing is effected by striking with a hammer on the head of the rivet, but so as that the head is

always kept close to the pipe. For this purpose the pipe must be supported a little with one hand while striking with the other.

The handle, *k*, may be substituted for the pedals, *e* and *f*.

Figs. 5, 6, and 7, represent a third machine for riveting pipes; it pierces and rivets at the same time.

The pipe, E, previously bent, and fixed by two or three rivets, is taken in, over the rod B, on a mandril, A, between the rollers, M and N, mounted in an upright, O, and which can be pressed together at pleasure by a screw, P.

Fig. 8.

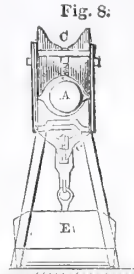
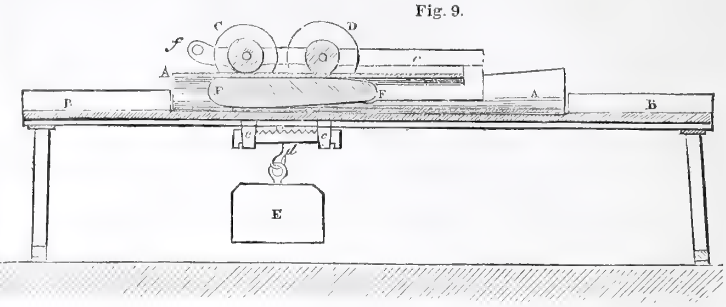


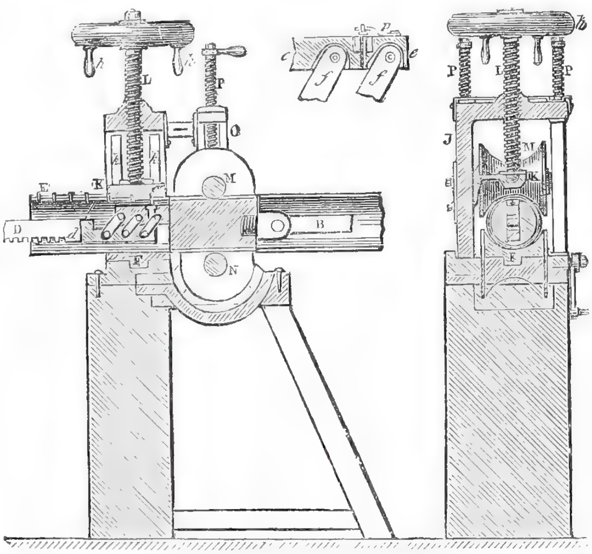
Fig. 9.



These rollers draw forward the pipe through a frame, J, in which it is supported by a cushion, F. In the frame, J, is fitted a block, K, sliding in the guides, *k*, and governed by a screw, L, with a fly-wheel, *h*, overhead. The block, K, carries a point, *g*, for piercing the plate.

At the end of the machine opposite the mandril, a long rack, D, enters the pipe, which rack is driven by a toothed wheel, and by a fly-wheel operating by friction. The extremity of this rack carries a jointed mechanism, one part of which is represented on a larger scale in fig. 7.

Fig. 5. Fig. 7. Fig. 6.



This mechanism is composed of a piece, *d* (fig. 5), which, by advancing against the mandril, raises, by means of the joints, *f*, another piece, *e*, till it bears against the upper and interior part of the pipe, and presents a resistance to the action of the punch, *g*.

The action commences by moving forward the rack, D, into the pipe, when the small block, *e*, rises. This being done, the punch, *g*, is brought down by means of the fly-wheel, *h*, and a hole is made. The punch is then raised, and the rack is moved back, with the jointed mechanism, *d*, *e*, *f*.

The block, *e*, carries a forked spring, *p* (fig. 7), in which a rivet is placed, and the mechanism is then driven back into the pipe, till it strikes against the mandril, A. The effect is as before mentioned; the piece, *e*, bearing upward, causes the rivet to enter the hole of the pipe; the latter advances between the cylinders, and the rivet is forced out from the spring. The sliding block, K, is then brought down, and pierces a new hole with its punch, *g*, while the other rivet is compressed and crushed between K and *e*.

Clasped Pipes.—Figs. 8 and 9 exhibit a back elevation and longitudinal section of a machine for clasping pipes.

In this machine the pipe is fixed, but the cylinders, as well as the mandril, are moveable.

B represents a trestle of cast-iron, having a neck of the diameter of the pipe to be formed, or a little larger. C and D cylinders or small rollers, narrow in the middle, for closing the clasped edges of the pipe, which is placed in the hollow between the necks of the rollers. The neck, *a*, of the roller, D, is a little larger than that of C.

If it be desired to make the clasped joining within the pipe, a groove must be made in the mandril, instead of the necks, *a*. This groove must be wider on the side F′, than on the side F.

E is a weight suspended to a rack, *d*, and rods, *c*, acting on the rollers. It is made to act more or less on one or other of the rollers, by moving it backward or forward on the rack, *d*.

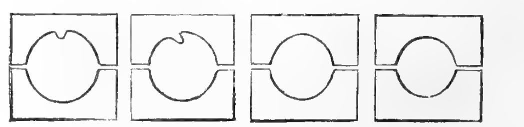
The mandril, F, is attached to a piece, *e*, which passes out from the pipe.

A plate of iron of the proper size is taken, bent round, and folded at the edges. One of the ends of this imperfect pipe is clasped on the beak of an anvil, and placed in the neck of the trestle, B. The small end, F′, of the mandril is then introduced into the clasped end of the pipe; and the rollers and mandril, being in one piece, are pushed forward to the other end of the pipe.

To cause the mandril and rollers to advance, force may be applied to the cross-piece, *e*, either by hand or in any other manner.

Figs. 10, 11, 12, and 13, represent four drawing-plate frames,

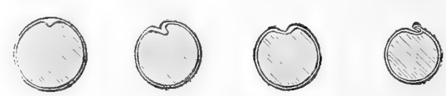
Fig. 10. Fig. 11. Fig 12. Fig. 13.



which may be joined together so as to form only one, and which are intended for making clasped pipes with the ordinary clasp of tin-plate workers.

Figs. 14, 15, 16, and 17, represent the cross sections of four

Fig. 14. Fig. 15. Fig. 16. Fig. 17.



mandrils, or of a single mandril cut into different parts, and surrounded with the pipe. The form of the mandril in each section is that assumed by the pipe which surrounds it, as it passes into the corresponding draw-plate.

The pipe-plate enters by cushion 10, and emerges by cushion 13. Mandril 14 shows the original form of the plate. On coming out of draw-plate 10, it has the form of fig. 15; and, lastly, in fig. 17, the clasped joining is shown in a perfect state.

Figs. 18 and 19 exhibit a new system of clasping, applied internally and externally. It consists in the use of a small ring of compressible material, such as lead, caoutchouc, &c., grasped between the two edges of the pipe by means of a long

sliding catch, *a*, of a malleable substance, which can be soldered. This arrangement may also be applied to riveted pipes, as shown in fig. 20.

Fig. 18.

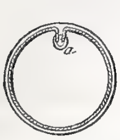


Fig. 19.

Fig. 20.

To move forward the pipes to be clasped or riveted, one may adopt the arrangements in figs. 21 to 23, in which the pipe rests

Fig. 21.

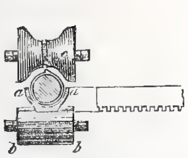


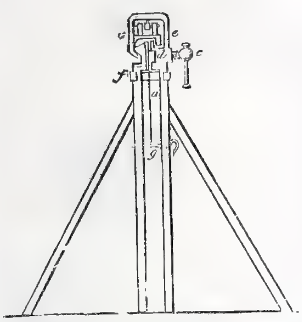
Fig. 22.

Fig. 23.

on a hollowed support, *a*, toothed or otherwise, advancing on the pinions or rollers, *b*.

Machine for folding the edge of the Plates.—Fig. 24 represents, in end elevation, a machine for folding the edge of the plates to be made into clasped pipes.

Fig. 24.



This machine is a kind of vice, the chops of which pinch or fold the plate, *a*, in its whole length. The edge to be folded passes beyond the chops of the vice. The plate is held fast by a screw, *c*, and a cross-piece, *d*. Horse-shoe curbs, *e*, and the curb, *f*, keep the vice shut.

Rods or bolts, *g*, support the plate while being folded at the edge.

To turn down the edge of the plate, a sliding piece, *b*, is worked above it, surmounted by an iron roller or pulley turning on a fixed axis. This sliding piece is formed beneath with an irregular conical groove, so as to operate gradually in pressing down the plate.

The plate being once brought between the chops of the vice, one or two inches of the projecting edge are beaten down with a hammer; the slide is then moved over the whole length of the plate, by which the entire edge is folded down.

Coupling of Pipes.—Fig. 25 represents a punching machine for executing a very simple system of coupling, which consists in fixing a collar of lead on the pipes.

Fig. 25.

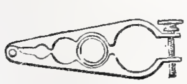


Fig. 26 is a longitudinal section of the ends of two pipes coupled by a new method. The ends of these pipes are fitted with square plates, fig. 27, between which is put a little mastic or red lead, and which are locked together by means of a coupling-piece, *a* (fig. 28), composed of two corresponding pieces, which are fixed together by rivets. The rivets are put at the edge of these plates, to allow them to have some spring.

Fig. 26

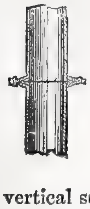
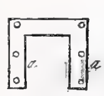


Fig. 27.

Fig. 28.



Figs. 29 and 30 show, in elevation and in vertical section, a machine for stamping, by pressure, screw-ends on the pipes, to admit of their screwing together.

A thick steel screw-tap, *c*, is introduced into the pipe, *e*. Three cylindrical cushions or grooved pulleys, *a*, *b*, *b′*, grasp the pipe, their grooves and position corresponding to the thread of

Fig. 29.

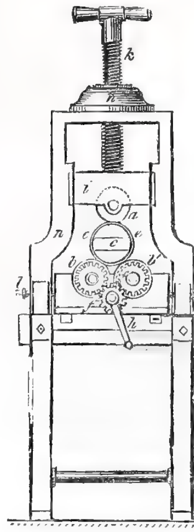
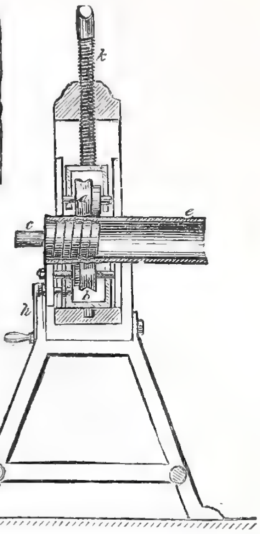


Fig. 31.

Fig. 30



the tap. The two rollers or pulleys, *b*, *b′*, are driven by a winch, *h*, and the wheels, *f*, *f′*.

The other pulley, *a*, is mounted on a cross-piece, *i*, moveable by means of a screw, *k*, in the frame, *n*, to allow of adapting its position to the diameter of the pipe.

Two screws, *l*, maintain in its place the frame of the pulleys, *b*, *b′*.

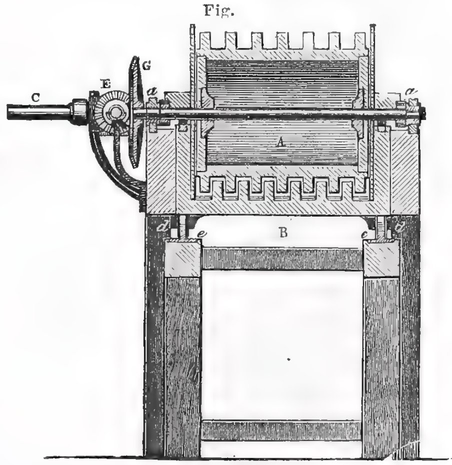
Fig. 31 represents, in vertical section, two pipes coupled together by this method.

MECHANICAL KNEADING-TROUGH.

BY M. DISDIER, OF MARSEILLES

There now exists a great number of kneading-troughs constructed on the metrical principle, though few of them have yet been brought into use in the baking business. A system which has been well spoken of, and has been applied with advantage, is that for which M. Disdier obtained a French patent in 1846.

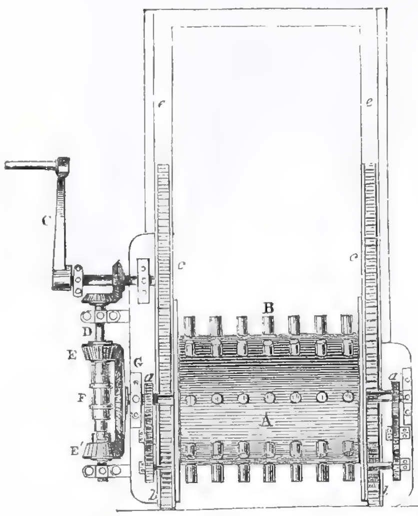
Fig.



It is distinguished by the addition of a kind of railway, on which the apparatus is moved with facility from one point to another.

Figs. 1 and 2, representing a vertical section and plan of this apparatus, convey an exact idea of its construction.

Fig. 2.



It consists, as will be seen, of a cylindrical drum, A, armed with teeth or projecting pins over its whole circumference, and a longitudinal trough, B, furnished with similar projections, between which those of A pass.

The movement of rotation is produced by means of a winch, C, the axis of which communicates by a pair of bevil-wheels with a longitudinal shaft, D, which carries also two conical pinions, E E′, and a muff, F, to bring them into gear successively with the wheel, G, and thereby to turn the drum alternately to the right and left.

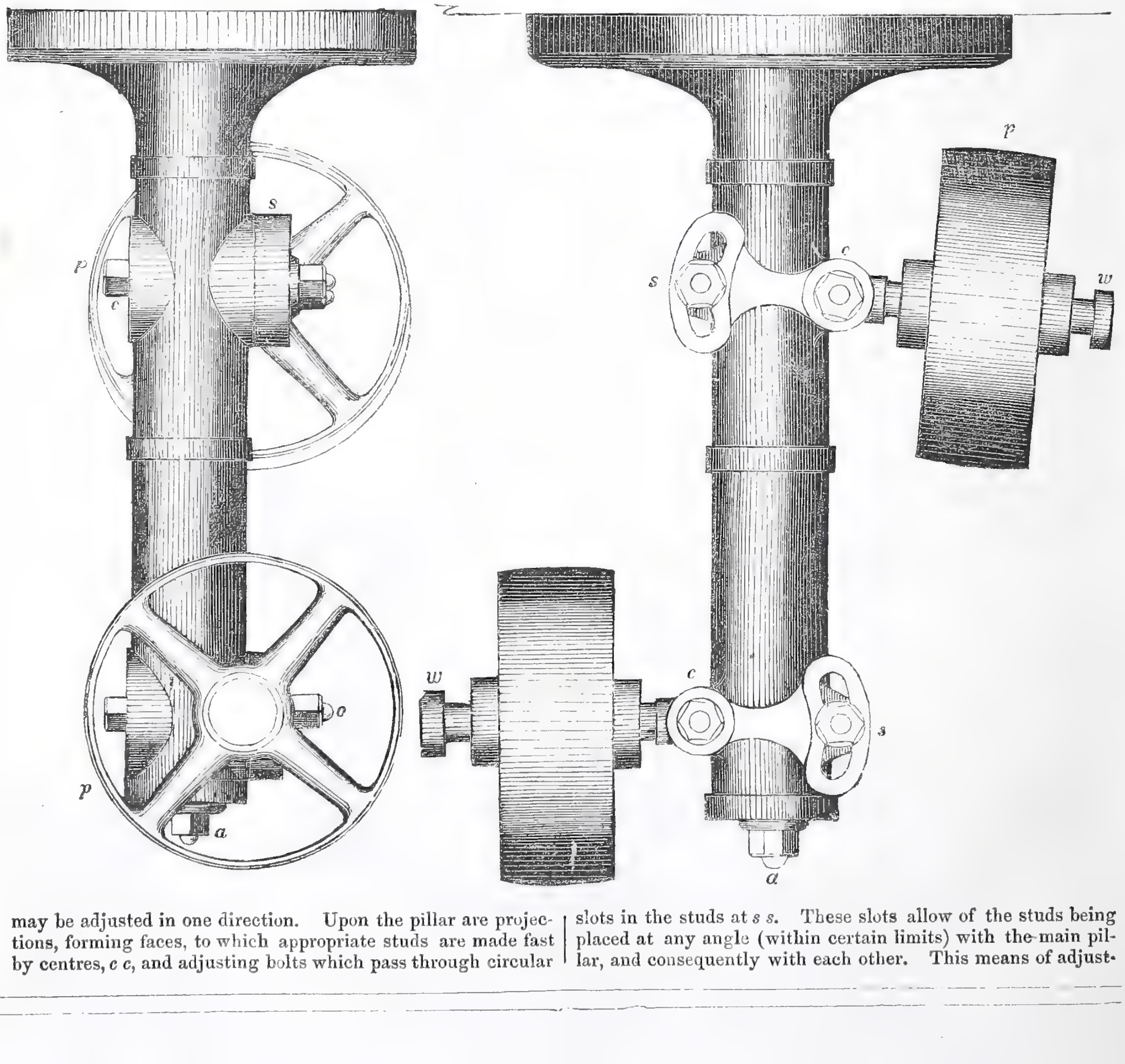
Pinions, *a*, fixed to the axis on each side of the drum, transmit, while slowering, the movement of rotation to two other pinions, *b*, which gear with the long racks, *c*, so as to drive the latter, and communicate motion at the same time to the moveable trough, B. This trough is furnished, for that purpose, with rollers, *d*, which run on the two fixed and parallel bars, *e*, forming, in fact, a railway.

Such an arrangement has much resemblance to the machine for kneading the paste which is used in the manufacture of ship-biscuits.

BELT GUIDE PULLEYS.

As the changing of the direction of belts is usually considered a troublesome matter in mill-work, perhaps the plan here figured and described, which has been found efficient in practice, may be considered worthy of attention.

The frame-pillar is made fast to a cross-beam, cribbing, or side-wall, by means of a long bolt, *a*, which passes up through the centre, and serves as an axis, upon which the whole frame



may be adjusted in one direction. Upon the pillar are projections, forming faces, to which appropriate studs are made fast by centres, *c c*, and adjusting bolts which pass through circular slots in the studs at *s s*. These slots allow of the studs being placed at any angle (within certain limits) with the main pillar, and consequently with each other. This means of adjust-

ment, together with that provided for about the axis, *a*, allows the guide-pulleys, *p p*, to be set at any position which may be required. The eyes of the pulleys are bored out to fit the studs, the journal part of which is made longer than the depth of the eyes to permit the pulleys to traverse laterally, and thus accommodate themselves to the irregularities of the belt, and distribute the oil. The pulleys are prevented from coming off by fixed washers, *w w*, upon the extremities of the studs.

A great many of these guide pulleys have been fitted up on the plan here described, and have uniformly been found to work well.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER III.

ROMAN PHILOSOPHY.

Among the Romans, as a nation, philosophy never flourished, save as an exotic. Immersed in the materialism of daily life, the speculative tendency rarely obtained any influence over them. The world presented to them objects to be conquered, killed, plundered, eaten, and what not, but rarely problems to be solved. In the latter period of the republic and under the empire, the various sects of Greek philosophy spread into Italy, where fashion drove the would-be literati to enlist under the banners of Epicurus, Plato, or Zeno. Idle disputation ensued in abundance, but no original views were struck out. The Roman imitators could merely reproduce the ideas of their Greek masters. Grammar and rhetoric were the main themes which occupied the schools, and sense was sacrificed to sound. This tendency is best illustrated in Cicero, who, inverting the natural arrangement, makes ideas subservient to words, just as a fop employs his body solely to display his clothing.

To this general character, Lucretius forms a striking exception. In his poem, *De rerum natura*, he develops the views of Democritus on the atomic constitution of matter. The arguments which he brings forward in support of this doctrine, are remarkably similar to those advanced by Sir Isaac Newton.

Several branches of science made, however, considerable progress during this period, chiefly indeed in the hands of Greek cultivators. As a native Roman, we may mention Vitruvius, the celebrated architect, who flourished during the reign of Augustus. His writings embrace a vast variety of subjects. In astronomy, he treats of the constellations, of the sun's course through the twelve signs, and of the construction of sun-dials. His tenth book, devoted to machinery, commences with a description of scaling-machines, wind-mills, and draught-machines, as also of the loom; then he proceeds to describe the wheel and axle, and pulley, water-mills, various machines for raising water, such as the screw, the water-organ, the pedometer, and other contrivances for measuring any distance travelled by land or water; and lastly, the battering-ram, tortoise, ballista, catapulta, and other machines used in the attack and defence of fortified places. His eighth book treats of rain-water, hot springs, mineral waters, the construction of aqueducts, and the conducting water in pipes, and the art of leveling. He describes likewise the preparation of cement, stucco, and of various colours, such as vermillion, ochre, verdigris, white and red lead. He had acquired a more distinct notion than any previous investigator of the transmission of sound, and the nature of undulations in air and water. Like many of the engineers and architects of the middle ages, he had evidently tolerably clear ideas concerning force and pressure, though unable to express them in a scientific form.

Celsus, who lived about the same time, is chiefly known as a medical author, though he wrote also on agriculture and rhetoric. In his age the medical world was divided into the three contending sects of empirists, dogmatists, and methodists. Celsus adopted the eclectic principle,* selecting from the views of each party what appeared to him correct. He contended against the doctrine of critical days in diseases, as an off-shoot of the Pythagorean numbers.*

The most noted man of science that Rome produced, was the elder Pliny, born A.D. 23. His great work is a kind of encyclopædia, or general survey of human knowledge; and while containing abundant evidence of the author's patient industry, yields too frequently proofs of his want of judgment. He commences with treating of the world at large, the elements, stars, and winds. Then follows a geographical survey of the then known world, an account of the generation and organization of man, a biographical sketch of the most eminent characters, with a history of inventions. Four books are devoted to zoology and anatomy; sixteen to botany, with an account of vegetable medicines. Five books treat of animal medicines, two of metals, one of colours and painting, one of stones and sculpture, and the last of jewels. Had this work been carried out in a manner worthy of its plan, it would have been a truly invaluable record of the learning, the arts, and the inventions of antiquity, and have spared us innumerable doubts and conjectures. But it has many serious imperfections. The author drew his accounts of the various manufactures, not from actual inspection, but from hearsay. Hence his statements are vague, erroneous, and unintelligible. In so doing he was doubtless influenced by that contempt for the industrial arts, so conspicuous a feature of ancient authors. To manufacture was the business of slaves. The learned passed over such matters with contempt, not imagining that they thus overlooked facts of the highest importance; phenomena which might have given a new and more healthy tone to their speculations. Pliny's great work bears the highest testimony to his zeal and activity, but composed, as it was, amidst the hurry and bustle of public life, its inaccuracies are numerous. In some cases he evidently misunderstood passages read by his secretary, and was thus led into errors. When authorities differ, he never appeals to observation or experiment. As a systematist in the natural sciences, he falls infinitely short of his predecessor, Aristotle. Devoid of the ability to perceive similitudes and differences, his classification is merely conventional.† His nomenclature is equally faulty, so that it is frequently impossible to identify his species. Yet his writings are not without merits of a high order. His thoughts are lofty and comprehensive. Like some others of his countrymen, he takes a more hopeful view of humanity than did the Greeks, and almost anticipates the modern idea of progress. Howsoever, therefore, his works may be depreciated by the worshippers of Augustan latinity, they are, to the philosophic reader, of far more importance than the elaborate declamations of Cicero.

On similar grounds, Seneca may claim a passing notice. This author, without having made any additions to science, expresses a full and even enthusiastic faith in its future progress. He is fully convinced of the regularity of all phenomena, and believes that the "laws" of this regularity will yet be made known.‡ To the historian of science, Rome has little further to offer, especially as the intellectual life of the ancient world found its last focus at Alexandria.

ALEXANDRIAN PHILOSOPHY—NEO-PLATONISM—THE MUSEUM.

Alexander of Macedon, in that immortal expedition whose idea was the overthrow of an effete despotism, the amalgamation of the East and the West, and the diffusion of Helenic art and learning, with a fine instinctive foresight founded the city of Alexandria. The young city rapidly acquired commercial importance, and on the dismemberment of the Macedonian empire, became the capital of the new kingdom of Egypt, and the residence of the Ptolemies, an enlightened and munificent line. Under their patronage we find a twofold intellectual movement taking place. On the one hand, general philosophy,

* Eclecticism, though sometimes temporarily convenient, is yet unsatisfactory. Above all, we must repudiate the doctrine advanced by Victor Cousin, that truth is necessarily elicited from a collision of errors.

* Periodicity, it has been demonstrated, plays a very important part in the phenomena of organic life, all regard to the mystical arithmetic of Pythagoras being abandoned. The births and deaths of animals, the crisis of diseases, the transformations of insects, do not occur equally and indiscriminately at every hour of the twenty-four, but in predominant numbers at certain definite periods.

† As an instance of conventional classifications, we may give the common division of vegetables into "trees, shrubs, and plants."

‡ He is supposed to have foretold the discovery of America.

resuming the hopeless struggle, calls in eastern mysticism to its aid. On the other, the various sciences, detaching themselves more widely from the parent stem, achieve real progress, either in a state of isolation, or in alliance with the arts. The former of these phases, as not strictly included within our plan, can claim but a brief notice. To avoid the troubles connected with the decline of their native country, many Greek philosophers had sought refuge in the new Egyptian city. Here their doctrines, amalgamated with the mysticism endemic on the shores of the Nile, burst forth into a new life, and for a time revived the decaying fabric of ancient civilization. Wild as Neo-platonism may seem, we cannot sneer at a system which for three successive centuries rallied around it the foremost thinkers of the world, which coped long, and often not unequally, with Christianity, and whose influence may be traced even to the present day in every form of mystical superstition. We are speaking of mysticism. What does the term denote? Stuart Mill happily defines mysticism as the ascription of outward existence to the creations of the mind; the belief that "by watching these, our own ideas, we can learn what passes in the world without." The mystic does not speculate; he contemplates. Instead of analyzing the universe, and thus grappling with its problems in detail, he seeks, by fixing his gaze upon nature, or upon a deity, to elevate his own being, until he can grapple with existence at once as a whole. Mysticism has enunciated lofty ideas, but they remain barren. It has frequently renovated our moral nature when degraded by a petty formalism, but it makes no discoveries. The Alexandrian philosophy was a development, or rather an exaggeration, of the Platonic doctrine of ideas, strongly tinctured by the oriental medium in which it flourished.* Ammonius Saccas, originally a porter, was the founder of the school; Plotinus, Porphyry, Proclus, and Jamblichus, his most eminent successors. Here again we find traces of that mystical arithmetic, of the connection of particular numbers with occult properties, which we have noticed in Pythagoras. The Alexandrians mingled faith with philosophy; like the ultra-transcendentalists of modern Germany, they called in the aid of "ecstacy" or "intuition" to solve problems to which reason is confessedly inadequate. This faculty of intuition is confined to a favoured few—a prudent limitation. If, therefore, any one fail at once to admit the conclusions of ancient Proclus or modern Schelling, the answer is easy. "You do not possess the gift of intuition; to reason with you, would be a mere discoursing about colours to a blind man." Thus Neo-platonism and transcendentalism answer the doubter. Yet a remark, and we must proceed. Was not the Alexandrian philosophy, notwithstanding the temporary resuscitation it effected in the speculative life of the ancient world, essentially a retrograde movement? Was it not a return towards the supernatural philosophy, the symbolism, of the primitive world? Were not Proclus and Plotinus farther removed from positive truth than Aristotle or Democritus? Undoubtedly. But this apparent anomaly in the progress of the human mind is easily explained. Mankind does not advance at a uniform speed. One land may have reached a high stage of enlightenment, whilst another remains wrapped in the conceptions of the infant world. If we attempt to transplant to the latter the doctrines of the former, they will be seen and appreciated by the light which it possesses. An amalgamation will take place, and the resulting system will be less mature, less advanced, than that of its original seat. The supernatural character of the Alexandrian philosophy was, therefore, no deviation from the general law of the evolution of our race.

The Alexandrian philosophy had also its martyrs. Here, also, the rights of thought had to be purchased with the blood of the thinker. Passing over lesser names, we come to Hypatia. Brought up by her father to philosophic pursuits, she, at an early age, became the wonder of the city. Her lectures attracted crowds of eager hearers. Her moral character, meanwhile, was worthy of her learning and eloquence. Cyril, the bishop of Alexandria, was not free from that enmity which the pulpit so generally bears to the platform. He could not bear to see the lectures of the female philosopher preferred to his sermons. Hypatia had remained attached to the ancient religion of her country—an excellent pretext for commencing hostilities. The prelate therefore lost no opportunity of stirring up the lower classes against her. Calumnies in abundance were set in circulation; the grave, abstruse discussions held in the house of Hypatia were described as being the most abandoned revels. Slowly the poison worked. At length the innocent and unsuspecting maiden is seized in the street by a frantic body of monks, and other representatives of popular ignorance and bigotry. They drag her in triumph to the principal Christian church; they tear the flesh from her bones with potsherds, and finally burn her mangled remains without the city walls, as a fit punishment for being more eloquent than a bishop, and more enlightened than monks. Why have the martyrs of the intellect found no Fox to record their sufferings?

If we observe the progress made by the individual sciences at Alexandria, we find a manifest improvement. Outward circumstances were eminently favourable. The vast commerce of the new Egyptian kingdom gave every opportunity for studying the productions—hitherto unknown—of the East. The phenomena of the tides, novel to the dwellers on the Mediterranean, were now open to observation. Geographical knowledge was widened. Geological facts were registered. The enlightened policy of the Ptolemies aided in every possible manner the advance of science. The celebrated Alexandrian museum, established under royal patronage, was the first instance of a scientific society. Its members, selected from the most learned men of the day, were supported by pensions, so that their whole time might be devoted to research. This institution was in every respect the type of its class. Science was, on the one hand, promoted by the joint labours of so many eminent men, but, on the other hand, the interchange of ideas was frequently checked by a petty jealousy, and admission into the museum was often dependent more upon influence than upon merit.* A zoological garden, or menagerie, was established at Bruchium, and the two libraries of Bruchium and Rhakitis contained the literature of the world. The former of these magnificent collections was destroyed by fire in the Egyptian war of Julius Cæsar; the latter, swelled by the Pergamenean collection, became afterwards world-famous as the "Alexandrian library," and is commonly said to have been destroyed by order of the Caliph Omar.† In addition to these advantages of situation, and these outward appliances, the Alexandrians evince an improvement in method. A far greater attention was paid to collecting and verifying facts. The power of collecting and harmonizing phenomena was indeed too often wanting, and hence few truths of value were reached. Thus, Alexandria offers us the two extremes; on the one hand, its mystical philosophers, bewildered in baseless reveries; on the other, its empirical savans, unable to ascend above desultory facts. In mathematical science we may notice Apollonius of Perga, Euclid (220 B.C.), who first elaborated a complete system of geometry from the scattered researches of his predecessors—famous, too, for his saying, "There is no royal road to learning."‡ The astronomical labours of Hipparchus have been already recounted. Eratosthenes of Cyrene, librarian at Alexandria, became celebrated as a geographer, and perhaps we may add, as a geologist. He wrote on the connection of mountain chains, the action of clouds, the alternate elevation and depression of portions of the earth's surface. In his time was undertaken the first measurement of an arc of the meridian, from Syene to Alexandria, in order to discover the true figure of the earth. Ptolemy, a scion of the royal house, is chiefly known from his astronomical labours. He claims our attention as having first indicated the laws of optical refraction. The anatomist, Galen, though born at Pergamus, studied at Alexandria,

* The reader will remember that Plato ascribes an objective existence to his "ideas."

* The day of learned societies is probably at an end. Their functions are now limited to hearing a few papers read, publishing transactions, and appending a string of initials to the names of all who can pay the fees. A systematic co-operation in research is out of the question.

† We are inclined to doubt the story. Rumours have reached us of portions of MSS, half buried in sand, seen in the vicinity of Alexandria. Parchment, we know, is very sparingly combustible, and could not possibly be used as fuel without a large admixture of other matter. Perhaps the treasure may yet be, in part at least, recovered.

‡ In our days, a warning against the notion of a popular road is more needful.

and must consequently be mentioned here. He attained a clear knowledge of the muscles, and is even thought to have distinguished the nerves of motion from those of sensation.

How far the Alexandrians might have proceeded, had they not been checked by the vicious influence of the ruling philosophy, and by the gradual decay of ancient civilization, is hard to conjecture. Their researches were, however, directed rather to the secondary than the primary sciences. Wherever experiment was needful to ascertain the laws of any phenomena, their method proved deficient.

We conclude our survey of the ancient period with a notice of those arts in which the physical and chemical knowledge of the world lay in embryo.

CHEMICAL ARTS OF THE ANCIENTS.

Seven metals only were recognized in the ancient world, gold, silver, mercury, copper, iron, tin, and lead. The gold, occurring in a native state, was the earliest discovered. The extraction of silver is likewise easy, and hence this metal was in use at a very remote epoch. The relative values of these two metals approximated much more closely than at present, an ounce of gold being equal in value to ten or twelve ounces of silver. Copper was likewise known at a very early period, and served not merely for money and household utensils, but for tools and weapons. The swords of the Homeric warriors are represented as made of copper. For this purpose it was hardened by the addition of a little tin. Brass, bronze, and various other alloys, were in common use. Their statuary bronze consisted of 100 lbs. copper, 10 lead, and 5 tin; their pots and caldrons of 100 lbs. copper, with 5 tin. Corinthian brass was an alloy of copper, with varying proportions of gold and silver. The two oxides of copper were known, in an impure state, and were used in medicine as escharotics. Verdigris was known as *œruge*, and was prepared as at present. *Chalcantum*, a mixed sulphate of iron and copper, was crystallized upon things, and served for blackening leather. Zinc, though unknown as a metal, was used in the preparation of brass. Its ores were obtained from Cyprus. The extraction of iron was a later invention. It was known, however, to the Egyptians, both in its ordinary state and as steel. Pliny was evidently unacquainted with the mode of smelting iron ores, and the preparation of steel.

Tin was obtained from Cornwall (Cassiterides). It was found in grains, which were separated from the soil by washing (stream tin). According to Pliny, it was frequently found in company with gold dust. It was of far higher relative value than at present, being worth nearly nine shillings per pound. It was used for lining copper vessels, and for making metallic mirrors. The art of tinning sheet-iron was unknown. Lead was obtained from Spain and Britain. It was used for the same purposes as at present, although, from the imperfection of the means used for its extraction, its price was 48 times greater. The alloys, *argentarium* and *tertiarium*, consisted of tin and lead, and were used as solder. Several preparations of lead were employed in medicine, such as *molybdena* (litharge), *cerussa* (white lead), and *cerussa usta* (red lead). The two latter were likewise used in painting. Mercury is first distinctly mentioned in the works of Pliny and Dioscorides. The latter proposes a method for extracting it from native cinnabar by sublimation, and may thus be said to have paved the way to the important process of distillation. Cinnabar served as a red paint, but no mercurial preparations were used in medicine, at least internally. The sulphuret and oxide of antimony were known, the former being used as a cosmetic, to communicate an intense black colour to the eye-lashes. Two of the sulphurets of arsenic were known to the ancients under the names *sardarache* or *arrenichon*, and *amipigmentum*.

Till recently, vinegar was considered as the only acid known to the ancients. It appears, however, probable that the Egyptians and Hindoos possessed nitric, and possibly also sulphuric acid. The former, like ourselves, employed a soluble salt of silver as a marking ink for writing upon linen. We can therefore scarcely avoid the conclusion, that they must have used nitric acid as a solvent for silver.

The only alkaline bases known were lime, potash, and soda, the two latter of which were generally confounded together. Their acquaintance with salts was of course very limited. Carbonate of soda was obtained in large quantities from Lower Egypt, under the name of nitre, and was employed for washing. It was rendered caustic by an admixture of quicklime. Under the name *alumen* (alum) the ancients confounded various substances, one of which appears to have been native green vitriol, whilst the other species were probably sulphates of alumina. We do not find any attempt to account for the difference between limestone and quicklime. Lime was employed as manure, as at present.

Sulphur was obtained native from the southern parts of Italy. It was employed externally in medicine, and its fumes, when kindled, served to bleach woollen cloth. Naphtha and asphalt were well known, and employed both in medicine and as fuel.

With the existence and properties of gaseous bodies the ancients were entirely unacquainted.

The species of minerals known were not numerous, but as the same name was applied to bodies of very different properties, if outwardly similar in appearance, it becomes very difficult to identify the descriptions of Pliny and other authors. Under the name *diamond*, they included also rock crystal, and perhaps hyalite. The name *emerald* was applied to emerald, beryl, green fluor spar, serpentine, nephite, and some ores of copper. Their opal was the same as ours, but the names topaz and chrysolite have been respectively exchanged. *Asteria* was perhaps our sapphire. Pliny's *amethyst* is the same as the modern stone of that name, though it sometimes also included sapphire. The sapphire of the ancients is described as being soft and opaque: it cannot be identified. *Lychnites*, which became electrical on heating, was probably a tourmaline. The name amber was sometimes applied to copal. *Gagates* was not agate, but jet or cannel coal. *Carbunculus* included the garnet and ruby.

The manufacture of earthenware appears, from the specimens remaining, to have reached a high degree of perfection, though no detailed account of the various processes has been handed down. Plaster of Paris was used for taking casts and impressions, as at the present day. Bricks of a very good quality were manufactured at Rome. In making mortar, they did not, like the moderns, slake the lime a considerable time beforehand, and allow it to spoil by the gradual absorption of carbonic acid, but added the sand without allowing the mass to cool. This accounts in a great measure for the superior durability of ancient cements. For so-called hydraulic mortar, the sand of Puzzoli was employed. The manufacture of glass must have taken its rise at a very early period, though the story of its accidental discovery, as related by Pliny, is probably fabulous. Articles of glass have been discovered by Layard and Botta in the ruins of Nineveh. It was rendered colourless in Pliny's time by the oxide of manganese, as at present. The stories of malleable glass, with which we are occasionally regaled by classic authors, are doubtless fabulous. As far as observation extends, the property of transparency appears inseparably connected with brittleness. The value of glass vessels was enormously high, two moderate-sized goblets having been bought by the emperor Nero for a sum equal to £25. This proves that the manufacture must have been very limited in extent. Many existing specimens prove that the ancients used glass of various colours for ornamental purposes. Their red glass—*hœmatinon* of Pliny—was tinged with the suboxide of copper. To communicate a green hue, the protoxide of the same metal was employed. Blue glasses have been found, stained with oxide of cobalt, with oxide of iron, and with copper. Almost all these varieties of stained glass were, however, deficient in transparency.

The art of cutting and engraving glass was practised nearly as at present.

The colours anciently employed in painting have been closely examined by Davy and others. The *reds* principally used were red lead, vermillion, and red ochre. The *yellows*, ochres, sometimes mixed with red lead or with protoxide of lead. Orpiment was also, according to Pliny, frequently employed. As a *blue* they used the so-called *cœruleum*, a frit of alkali and

silica, fused with oxide of copper. Their *greens* were carbonate of copper mixed with carbonate of lime. Their purple was a lake, formed with the juice of the Tyrian purple snail. Indigo was also known under the name *purpurissum indicum.* The *whites* were carbonates of lead and lime; the *blacks*, lamp black; the *browns*, ochres and oxides of manganese.

The arts of dyeing and calico printing flourished at a very early date. The Egyptians, according to Pliny, were evidently acquainted with the use of mordants and resists, and were thus enabled to produce different colours upon a piece of cloth by a single immersion in the dye-vat. Madder, archil, wood, indigo, and the Tyrian purple, were the chief dye-drugs.

The manufacture of soap originated among the Gauls and Germans, and was thence introduced into Rome. It was of two kinds, hard and soft. Starch was manufactured from wheat, by a process very similar to that still followed. It was brought from Chios, Crete, and Egypt.

The preparation of wine and of beer (in Egypt and Germany) was early known, but the ancients do not appear to have acquired the art of separating alcohol from fermented liquids by the process of distillation.

Leather was in common use, but of the ancient method of tanning no description has reached us.

From the numerous allusions found in the poets and historians of antiquity, it is evident that the art of secret poisoning was extensively cultivated, and many distinguished characters are supposed to have lost their lives in this manner. According to Theophrastus, a poison was known which could be regulated so as to prove fatal in any period of time from two months to a year, or even beyond. It was prepared, as he states, from *aconitum*, and was incurable. The sea-hare, *lepus marinus*, an animal not perfectly identified, supplied also a formidable poison. The feebler* and more easily detected poisons of mineral origin were not often employed. The absence of chemical analysis, and the inability of medical men in those times to distinguish the results of poison from the symptoms of natural disease, may have greatly aided Locusta and her compeers in their deadly vocation.

The medicinal art† takes its systematic origin with Hippocrates of Cos, the friend of Democritus, who, if we are inclined to believe in ancient chronology, was born about 460 B.C. He was at once an acute and faithful observer, and a profound reasoner, and raised his art to a point, beyond which it has only been able to advance in comparatively recent times. Instead of the *à priori* system followed by his contemporaries, he proceeded to generalizations, after a comprehensive survey of phenomena. His knowledge of physiology, pathology, and of the medicinal properties of vegetable and mineral substances, was truly surprising. He first discovered the important law of periodicity in organic life. His accuracy in noting the leading features of disease merits the highest approbation. Theophrastus (870 B.C.), though versed in all the science of the times, may perhaps rank here on account of his contributions to botany, then viewed as an integral part of medicine. His "History of Plants," of which only some fragments have reached us, contains much valuable matter, mingled with a few fables. He was acquainted with the sexes of plants, and may be termed the founder of vegetable physiology. He established a botanic garden. His work on mineralogy was of the greatest value to Pliny.

Considerable attention was paid to medicine at Alexandria. Herophilos, who flourished under the first Ptolemy, introduced the dissection of the human body, for which purpose the government placed at his disposal the remains of all condemned criminals. This facility for studying anatomy raised the medical school of Alexandria to the highest pitch of eminence. Herophilos is the first author who gives an accurate account of the brain, and the origin of the nerves. He discovered the lacteals, though he was unacquainted with their function. It was at Alexandria that the two rival medical sects of dogmatists and empirics took their origin. The former insisted on a knowledge of the structure and functions of the body, of the effects of disease, and the action of remedies. The latter (who in our day would have styled themselves "practical men, and worshippers of common sense,") denied the necessity for any such knowledge, and insisted upon mere unregulated experience.

The first physician of note who practised at Rome was Asclepiades of Bithynia, who flourished in the first century B.C. He divided diseases into acute and chronic, and paid great attention to diet. Among his followers arose the sect of the methodics, who hold an intermediate rank between the above-mentioned parties. Celsus, who lived in the Augustan age, does not implicitly follow any of these parties. He collects in his work the digested experience of the previous ages, and shows a considerable acquaintance with anatomy, pathology, pharmacy, and surgery. With the exception of Galen, no medical author appeared in the later ages of the Roman empire. The commentatorial spirit proved fatal to original study, and the art of medicine gradually declined to a most wretched condition.

Such being the state of the arts, the reader will easily perceive how very limited was the amount of chemical and physical knowledge possessed by the ancients, even in what we may term a latent state. Manufacturing industry did not then, as now, absorb all the practical energies of the people. War was the chief business of the free population, whilst the arts, viewed with comparative indifference, were abandoned to slaves. Let us, however, never forget that this predominant military spirit had its own important part to play in the development of the world. Without it and war, it is highly questionable whether the natural sluggishness of our race could ever have been overcome. The camp was the first great school of social organization, as well as of continuous activity for a given purpose. That war, like slavery, has now entirely or almost fulfilled its mission, and in consequence generally impedes the progress of civilization, is quite a different affair.

Such, then, was the intellectual development of the Græco-Roman-Alexandrian period in its inward or speculative, as well as its outward or practical phase. We find its general philosophy still metaphysical, and as such stationary and unsatisfactory, whatever valuable ideas it may contain, and how brilliant soever the evidence given of the talent of its cultivators. Its principal service to mankind lies in the exhaustive trial of almost every form of speculative error. We perceive that "moral" philosophy has been separated from the study of the universe, happily for the latter, which is thus enabled to progress untrammelled. One science, mathematics, has become eminently positive, and appears as a grand model and prototype for the rest. Astronomy, following after, attains its rudimentary constitution in the schools of Alexandria. Physics, chemistry, physiology, are not yet definitively constituted; they lurk on the one hand in the vague speculations of the general philosophers on the powers of nature and the functions of life, and on the other in the empirical processes of art. The intellect has therefore progressed, although, as it may seem to us, slowly. But the outset is ever the most difficult. To acquire the first notions of the true nature of scientific explanation, is a far harder task than subsequent discovery. To the race, as to each individual, education was in the beginning a painful task.

We cannot close the survey of this period without one remark, which popular prejudices render necessary. Whatever progress had been made by the ancients in science was confined to a very few individuals. A large part of the population in Greece and Rome was in a state of slavery, and as such debarred from all the rights and privileges of freemen, and even among the latter the majority were ignorant boors, beyond the reach of education, even in its most rudimentary aspect. We have seen that many of their philosophers avowedly, and on principle, sought to conceal their doctrines from the multitude. We remember that the art of printing, without which universal education is inconceivable, was then unknown. When, therefore, certain people, seeking to prove that intellectual cultivation has no ameliorating influence upon the moral condition of a nation, point to Greece and Rome as an instance in their favour, they

* We say expressly *feebler*, to remind our readers that, contrary to vulgar prejudice, arsenic and corrosive sublimate are innocent in comparison with the poisons derived from the organic world.

† The term "medical science" appears to us erroneous. The physician requires a knowledge of various sciences, but his function is practical, not speculative, and must therefore be termed an art. The very name "physician," by the by, is a barbarism.

are simply *raving*. The world has hitherto seen no example of an educated nation, and narrow as is the basis of mental training in our own "highly favoured country," in the most palmy days of antiquity it was far narrower.

AGRICULTURE.

CHAPTER XVI.

MANAGEMENT OF THE DAIRY.

The present chapter is intended to give an account of the mode of managing milch cows and their produce in Gloucestershire, and in the sandstone districts of Scotland. And in doing this we shall be enabled to state the nature of the changes that take place in milk and cream.

In Gloucestershire a great part of the land is under permanent pasture, and to every hundred acres twenty-five cows are allotted. But this quantity of land, besides the cows, keeps the young stock that are raised to keep up the number of milch cows. The cows usually have their first calf at three years of age, and are disposed of at seven or eight to graziers. In this way about a quarter of the old animals are sold every year.

A three-years-old cow, newly calved, sells for from £14 to £18, and a discarded one from £8 to £12. Of the calves not intended to be kept, many are sold when a few days old to the butchers, and from 8s. to 15s. are obtained. If they are kept until they are weaned, *i.e.*, until about two months old, somewhat more is of course got for them. They do not receive very much milk, but have meal given to them.

Strange as it seems, the cows, as a rule, live in the open fields all the year round. Each cow is considered to require for pasture an acre and a half. In the winter, hay is carried into the fields, and two and a half tons of this, which is obtained from another acre and a half, is the average quantity consumed in the winter.

It is not possible to conceive anything so bad as this mode of managing the land and feeding the cows. Nevertheless, the Gloucester cheeses are perhaps unequalled.

In summer the cows are milked at five in the morning, and again at three in the afternoon. As soon as it is drawn it is taken to the dairy, poured into the cheese-tub, and then has the annotto and the rennet mixed with it. In autumn or winter, when the temperature is cold, a portion of it is warmed, so as to raise the whole to a temperature of about 85°. After the rennet has been added, the vessel is covered up with a cloth and left for an hour. At the expiration of this time the curd is formed.

This curd is minutely broken down with a three-bladed knife, and then allowed to repose for a little to let the whey come to the top to be drawn off. The process is then repeated, but much more cautiously, so as not to press out any of the butter. When the whey is effectually separated, it is ready for being placed in the vat. The following is an account of its management:—"A cheese-cloth, made of fine canvas, is spread across the mouth of the vat; the curd is then lifted from the tub by the hands and laid upon the cloth, and pressed equally down. When all the curd has been placed in the vat, the ends of the cheese-cloth are tucked up and folded inversely, with as few creases as possible, upon the top, and covered with a circular board made exactly to fit the inside of the vat. It is then put in the press for half-an-hour and tightly pressed, after which the partly consolidated curd is taken out, cut in slices, and passed through the curd-breaker, which reduces it to small crumbs without squeezing out the fatty matter. The comminuted curd is again returned to the vat, and firmly pressed into it by the hands while filling. A dry cheese-cloth is next spread over the mouth of the vat, which is then turned upside down, and the curd turned out with the cloth. The vat is now rinsed with whey and dried, and the curd still in the cloth placed in it. The ends of the cloth are then placed neatly and evenly over the top, as before, and covered with the cheese-board or another cheese-vat, if more than one cheese is to be placed in the same press. The vat is allowed this time to remain two hours under the press, when it is again taken out, and the cheese, now in a fine solid state, is pared at the upper edge, if necessary; thereafter inverted, and put in a clean dry cloth, and again pressed. There are usually two or three presses employed, each heavier than the others, and ordinarily it takes about four or five days for a cheese to go through these presses, beginning with the lightest and ending with the heaviest."

After the cheese has been from twelve to twenty hours in the press, it is considered time to salt it. This is done by rubbing in the salt by the hand. This is repeated until about every thirty pounds of cheese have received about one pound of salt. When a cheese has been salted and sufficiently pressed, it is ready for removal to the drying-room. In this place they are turned every day, and when considered sufficiently dry are scraped, and—a process which surely might be omitted—painted red.

Very little butter is made in Gloucestershire. About a pound of *whey* butter is obtained per week from each cow during the summer season. A still less quantity of *cream* butter is made, nearly the whole of the raw milk being appropriated to the manufacture of cheese.

One great cause of the superiority of Gloucester cheese may be the extreme attention that is paid to cleanliness in the dairies.

A cow in Gloucestershire is considered to yield about five hundred gallons of milk in the year. From each animal about three, or from that to three and a half, hundred-weight of cheese are obtained. Besides this, from forty to fifty pounds of butter are obtained. The whey is given to pigs, and is worth a little. In addition to this, the amount of milk given to the calves that are bred up, although not very great, must be taken into account. In mixed husbandry, the excrements of a cow per annum would be calculated at, at any rate, from thirty shillings to a pound; but in Gloucestershire, where they are pastured all the year round, it cannot be taken at more than a mere trifle. The produce, then, of a cow annually in this part of the country is,—

	£	s.	d.
500 gallons of milk made into cheese, at 6d. per lb., each gallon yielding one pound,..........	12	10	0
20 lbs. of cream butter, at 11d.,..................	0	18	4
30 lbs. of whey butter, at 9d.,....................	1	2	6
Whey to pigs,..	1	5	0
Calf,...	0	10	0
Manure,...	0	0	0
Total,..	£16	5	10

The cost of keeping the cow consists in the rent of three acres of land, the expense of making half of this into hay, the servants, the annual deterioration in the value of the cow, and the interest on the capital. Perhaps the annual profit upon each cow is not £4. To the other expenses, the risk of the animal's dying from pleuro-pneumonia or other infectious diseases must be added.

The difference between a single Gloucester cheese and a double one is not, as is sometimes supposed, that the double is made of new milk and the single of a mixture of half new and half skimmed, but merely relates to size. A single Gloucester cheese has eight to make a hundred-weight, a double only five, and as the thicker cheese takes the longer time to mature, it sells for more money, although it perhaps remunerates the producers to a lesser degree.

If we presume that a profit of four pounds is made per cow, and that each cow occupies three acres, this leaves a profit of about seven and twenty shillings per acre.

Upon mixed husbandry farms cows are kept, but the manufacture of butter and cheese is altogether subordinate to the rearing of young stock upon the milk. The animals are, however, far better treated, but unfortunately, owing to the imperfections of the dairy-maid, the cheese always, and the butter generally, are much inferior to the butter and cheese of the English dairy districts.

Upon a mixed husbandry farm of two hundred and fifty acres, from six to a dozen milch cows are usually kept. If it can be conveniently managed, the cows calve about March. Besides the calves borne by the farmer's cows, he usually purchases some more, either from his own servants or from town

dairy-men. His object is to have at any rate three calves for every two cows.

As soon as a calf is born it is taken away from the cow-byre, and, of course, fed by hand by the dairy-maid. These calves are fed thrice in the day, that being the number of times the cows are milked. At first they receive at each meal a quart and a half of new milk. By the time they have attained the age of four weeks, this has been gradually increased to six. After this age the milk is still further increased until they are twelve weeks old, when they receive eight quarts, and during the last four weeks they usually have, mixed with their milk, either oat meal or linseed meal. Of these latter substances they get from a quarter to the whole of a pound a day. When they are twelve weeks old they are put upon the grass, receiving for a time, however, two meals of milk a day, one at night and another in the morning. By-and-by the night's meal is dispensed with, and in the course of two or three weeks the milk and meal are altogether discontinued. On an average, from the time a calf is born to the period of its complete weaning, it consumes about a hundred and twenty gallons of new milk and twenty-eight pounds of meal.

The remainder of the milk produced by the cow is either consumed as milk or made into butter and cheese. The two latter are done unskilfully. The milk is put into earthenware basins to allow the cream, which has a lower specific gravity than the milk, to float to the surface. The cream is then skimmed off and put into a deep jar, until as much is collected as suffices for a churning. Of the skim milk that is left cheese is made, and the following is the process followed:—A part of it is warmed sufficient to raise the temperature of the whole to about 90°. Then the rennet, or yearning, as it is called, is added. The remainder of the process is thus described:—"Half a pint of rennet is employed to coagulate twenty gallons of milk, and the coagulation seldom takes longer than an hour in being completed—more frequently only half an hour, and sometimes less. The high temperature of the milk and the strength of the rennet tend to hasten the process much more than in Gloucestershire and Cheshire, where it is a material point to keep the temperature of the milk low, and the rennet just sufficiently strong to effect curding in an hour or an hour and a half. When the curd is completely formed, the arm is plunged into the mass, and the whole gently stirred until the whey separates. A cloth strainer is then placed on the top, pressed down, and the whey removed as it rises through it. When the most of the whey has been got rid of in this way, the tub is tilted to one side and the remaining free whey allowed to run off, while the curd is retained by the hand, a bit of board, or the skimming dish. The curd is then put into the wet cloth already used, which is tied at the corners and suspended on a stick placed across the top of the tub. As soon as the whey ceases to drop from the strainer, the curd is salted, put in the cheese vat, and placed underneath the press. In a few hours it is taken out, the cheese vat dried, a clean dry cloth placed in it, and the cheese, which has been pared at the upper edge, inverted, replaced, and returned to the heaviest press, the full weight of which is let down upon it. This generally concludes the first day's work. On the second day the cheese is turned twice or thrice, and each time inverted in the vat and a dry cloth used. At the end of the second day the cheese is taken permanently out of the press, then laid on a dry shelf to ripen, being turned every day and wiped dry with a towel. In many cases, however, skimmed milk cheese-making is completed in one day, being only turned twice after the salt is applied; but as heavy pressing must be resorted to at the very commencement of the process, when the curd is soft, no insignificant portion of the oily matter is squeezed out. In general, these skimmed milk cheeses are very poor, especially if the cream has been allowed to remain long upon the milk; but when well made they are very palatable, and, being mostly pure casein, make excellent nourishing food, along with bread or potatoes, for working people, to whom they are generally sold by the farmers' wives. Skimmed milk cheese is ready for market in two months, and is generally sold at 3d. per lb."

Sweet milk cheeses are sometimes attempted upon Scottish mixed husbandry farms, and occasionally very good ones, as good, in fact, as Gloucester ones, are produced. But farmers rarely trouble with such, and they are generally made by the dairy-maid of the home farm. From twenty gallons of skim milk, more than twenty pounds of cheese may be calculated upon.

Upon many of the farms now alluded to very good butter is made, and, indeed, more attention is paid to butter-making than to cheese-making. The cream, as we mentioned, is separated from the skim milk and kept in jars, usually for either a week or for half that time. It is at the appointed time agitated in a churn until the butter separates from the whey. The butter is then washed among fresh water until it is quite free from whey. It is then made up for immediate sale, contrary to the English plan, either without any salt at all, or salted for winter use.

It was found that a hundred gallons of milk gave five and five-fifths of a gallon of cream, and that this cream, when churned, produced twenty-seven and a half pounds of butter, *i.e.*, one pound of butter was obtained from fourteen and a half quarts of milk.

The cows are far better and more rationally treated than on the English dairy farms. In summer they are pastured, and in winter they are fed in byres upon turnips and straw, the manure that is derived from a cow rather more than compensating both for the straw she consumes and destroys in bedding. The following is a calculation of the cost and receipts of a cow:—

	£	s.	d.
Grass, $2\frac{1}{2}$ acres, at 40s.,	5	0	0
Turnips, $9\frac{1}{2}$ tons, at 7s. 6d.,	3	11	3
Interest on value,	0	10	0
Attendance,	0	10	0
	£9	13	3

We must, however, observe that the extent of grass land put down here appears to us much too great, although the turnips are perhaps put down at too little. The estimated produce is as follows:—

	£	s.	d.
Calf, (newly dropped),	1	0	0
180 gallons of milk to calves, at 4d.,	3	0	0
338 do. for four months give butter, 93 lbs., at 10d.,	3	17	6
And cheese, 256 lbs., at 3d.,	3	4	0
86 gallons of milk, in three winter months, give butter, 17 lbs., at $8\frac{1}{2}$d.,	0	12	$0\frac{1}{2}$
80 do. skimmed milk, at $2\frac{1}{2}$d. a gallon,	0	16	8
21 gallons buttermilk, at 2d.,	0	3	6
222 gallons of whey, at 1d.,	0	18	6
	£13	12	$2\frac{1}{2}$
Deduct cost,	9	13	0
Profit,	£3	19	$2\frac{1}{2}$

We may farther quote this intelligent writer to state that the cost of producing a gallon of milk in Gloucestershire is $6\frac{1}{8}$d., while in Scotland (Fifeshire), it is $3\frac{3}{8}$d.

We cannot pretend to describe in detail the usually very simple implements of the dairy. We prefer confining ourselves to noticing Drummond's Patent Churn, which would really appear to possess superior qualities. We abridge an account of this implement, made public by Messrs. Young, who have acquired the patent right. It is of an elliptical form, divided in the middle into two chambers, which freely communicate at top and bottom by means of holes. To each of these chambers belongs a staff and a dasher, similar to those in the old-fashioned plunge churns. The churn is set into an iron stand, with an elliptic iron bracket attached, supporting two wheels, one a fly one and the other oscillating, the latter acting between the upper ends of the two staffs, and merely attached by means of two leathern belts. To the fly-wheel there is a handle, by which it is driven round, and which acts upon the oscillating wheel by means of a rod, and which thus effects a hundred strokes in a minute, and this upon the application of very little

PLATE VI

power. The one staff, as it is propelled downwards, forces the cream through its dasher, and likewise through the division at the bottom into the other compartment, the other simultaneously forcing itself through the cream upwards, and in the same manner causing a cross action through the holes perforated at the top, and *vice versa*, thus combining very rapid action, with, at the same time, securing a constant injection of fresh air at each stroke. The practical advantages of this churn are, the ease with which it is worked, and the extreme rapidity with which the separation of the butter is effected, namely, from two to five minutes.

The properties of milk, and the changes that take place in it during the different operations of the dairy, are now very well understood. It is proper here to present a summary of them. Milk consists of sugar, of oil (called butter), of casein, some salts, and water. The proportion in which these exist vary in the milk of animals, as is shown by the following table:—

Milk of—	Woman.	Cow.	Ass.	Goat.	Ewe.
Casein,........	1·52	4·48	1·82	4·08	4.50
Oil,............	3·55	3·13	·11	3·32	4·20
Sugar,.........	6·50	4·77	6·08	5·28	5·00
Salts,.........	·45	·60	·34	·58	·68
Water,........	87·98	87·02	91·65	86·30	85.62
	100	100	100	100	100

The small quantity of butter or cream contained in asses' milk is very striking.

After the milk is drawn from the cow, the vital affinities that kept the carbon, oxygen, and hydrogen so combined as to form sugar cease, and the sugar is gradually converted into another compound of these elements of an acid nature, and called lactic acid. When this change has taken place, the country people say that the milk has soured.

The fat of the milk, or the butter, exists in globules, and is mixed up with the water of the milk. These globules, when the milk is at rest, gradually ascend to the surface, taking with them a little casein, water, and either sugar or lactic acid formed from the sugar. This compound can be skimmed from the surface, and constitutes what in ordinary language is called cream. If this cream be heated, the globules of fat burst and unite together. Being lighter than the other constituents of cream, they ascend to the surface, forming an oily fluid. When this cools it becomes solid, and is, in fact, pure butter. When butter is procured in this manner, it will keep a long time without becoming rancid, but it has not the taste of butter as sold in the shop, and is not used as an article of diet.

When it is wished to make butter to serve for food, a very slight elevation of temperature is applied, and its source is mechanical agitation. The cream is put into a churn, the flappers or dashers of which are made rapidly to move through it. When by this proceeding the temperature is raised from 4° to 10°, the globules burst and adhere together. Butter made in this manner, besides fat, contains a little sugar, a little casein, and very often an aromatic principle derived from the food of the animal. The mixture of this principle and of the sugar with the fat renders the whole agreeable to our palates, and this is the form in which we take butter.

Butter made in this manner will not long keep fresh. The sugar is converted into lactic acid, and the mass becomes rancid. If a mass of sugar be artificially added, this change does not take place. Common salt and saltpetre have a like power of preserving butter; and, in practice, a mixture of the three is added to butter in the autumn to make it keep over winter.

Casein is easily separated from new milk, skim milk, or buttermilk, by adding an acid. When this is done, the curd or casein falls down to the bottom. The reason of this is, that casein forms a compound with soda that is soluble in water. Now new milk contains carbonate of soda, and the casein combines with it, and is then dissolved in the water of the milk. But as the sugar of the milk is gradually converted into lactic acid, the lactic acid combines with the soda and forms lactate of soda, and the casein, now insoluble in water, falls down to the bottom in lumps, having a quantity of water in which the salts are dissolved, *i.e.*, whey, mechanically mixed with it.

When it is wished, however, to obtain this casein for the purpose of cheese-making, the dairy-maid does not wait until the lactic acid is formed, but adds some other acid to combine with the soda. The one fixed upon is muriatic acid, because it, when it combines with the soda, forms common salt, which communicates no unpleasant flavour. Owing to custom, the muriatic acid is not bought from the druggist's shop, but the stomach of a calf, which contains a little, is used. When this is added to milk, the casein falls to the bottom. The manipulations we have previously described have for their object the separation of the whey from it.

CONCHOLOGY.

CHAPTER IV.

ORDER IV.—TRACHELIPODA.

Posterior portion of the body spirally convolute, and separated from the foot, and always enveloped in a shell; foot, free, flattened, and attached to the inferior base of the neck, or the anterior portion of the body, and forming a member of locomotion; shell spiral and enveloping, with a canaliculate aperture, notched or effuse at the base.

GRAND DIVISION I.—ZOOPHAGOUS TRACHELIPODA.

Animals always inhabiting the ocean, and feed upon other animals; provided with a protruding siphon, and respiring water only, which is conducted to the branchiæ by this siphon: they are destitute of maxillæ, and have a rectractile proboscis.

TRIBE I.—INVOLUTE.

Shell without a canal, but having the base of the aperture notched or effuse; the spiral convolutions broad, compressed, and rolled up in such a manner that the external one almost entirely envelopes the others.

Genus.—Conus.—*Linnæus.*

Generic Character.—Shell inversely turbinate, conical; spire generally short; aperture longitudinal, linear, entire, narrow, and sub-effuse at the base; columella smooth, and destitute of teeth; outer lip sometimes emarginate above.

Section 1.—Spire short.
Section 2.—Spire elongated.
Section 3.—Shell ventricose.

Conus scabriusculus. Plate III. fig. 43. Found in the London Clay at Barton.

Conus antediluvianus. Plate III. fig. 42. Found in the London Clay.

The shells of this genus are marine, and are by no means numerous in a fossil state; they are, however, found sparingly in England, in the Crag and London Clay; the *Calcaire-grossier* of France, the *Terrains Cacareo-trapeeus* of Brongniart, and contemporaneous strata of other countries. Mr. Phillips and Mr. Conybeare mention some imperfect casts, which they have noticed in the Inferior Oolite; but these are not positively ascertained to belong to this genus.

Genus.—Oliva.—*Bruguière.*

Generic Character.—Shell oblong, subcylindrical, convolute, smooth, and glabrous; spire short, the volutions separated by a narrow canal, above which the volutions are coated with a fine enamel; aperture elongated, rather narrow, and notched at the base; columella obliquely striated or plaited, its base provided with an oblique, somewhat tumid, striated, varix-like appendage.

Oliva Salisburniana. Plate III. fig. 44. Found in the London Clay.

The shells of this genus bear a considerable resemblance to those of Ancillaria, but are readily distinguished by the canali-

culate suture which separates the volutions, as well as by the striated columella; they are also recognized from the Volutæ and Mitræ by the same characters.

All the Olivæ are marine shells, principally natives of tropical climates. None are found in the British seas.

But few fossil Olivæ are known; these are found in the London Clay and *Calcaire-grossier;* and one species occurs in a sort of Greensand, near Turin.

Genus.—Ancillaria.—*Lamarck.*

Generic Character.—Shell oblong, subcylindrical; spire short, seldom more than a third of the length of the shell, the suture is not canaliculate, and is generally obscured by a coating of enamel, which frequently covers the whole spire; aperture longitudinal, narrow above, effuse and notched at the base; lower portion of the columella smooth, with an oblique, tumid, usually striated varix at the base; entire outer surface smooth and glossy, supposed to be devoid of both epidermis and operculum.

The columella being devoid of plaits, distinguishes the shells of this genus from those of the genus *Oliva;* and the callous, oblique band at the base of the columella, separates them from those of the genus *Terebellum;* they have sometimes been mistaken for a species of the genus *Melanopsis*, which are invariably fresh-water shells, more particularly the fossil species; but the latter genus may readily be distinguished by the tumid upper portion of its pillar lip, and by the spiral line being distinct, and in the outer surface not being polished.

Ancillaria subulata. Plate III. fig. 40. Found in the upper marine formations.

The *Ancillaria* are marine shells, and principally inhabitants of tropical climates. The fossil species are very limited in number; they chiefly occur in the London Clay, *Calcaire-grossier*, and Greensand.

Genus.—Terebellum.—*De Montfort.*

Generic Character.—Shell thin, convolute, subcylindrical, rolled around its longitudinal axis in the form of an elongated cone; spire short, sometimes hidden; aperture longitudinal, narrow above, and ascending in the form of a straitened spiral canal, defining the volutions; the outer lip entire, and not thickened, diverging as it descends, widely expanded, and notched; columella smooth, truncated at the base.

Section 1.—Spire visible.

Terebellum fusiforme. Plate III. fig. 41. Fossil, in the London Clay.

Section 2.—Spire invisible, or slightly apparent.

Terebellum convolutum. Plate III. figs. 47, 48.

Montfort considered the concealed spire sufficient reason for forming a separate genus of this last species, under the name of *Seraphs;* but it appears to be only in the adult state that it assumes this character, because, if broken, the spiral canal is distinctly visible.

The shells of this genus inhabit the Indian Ocean, of which one recent species only is known.

Genus.—Cypræa.—*Linnæus.*

Generic Character.—Shell strong, particularly in front, ovate, or oblong-ovate, convex behind, and somewhat flattened in front; margins involute; spire very small, generally hidden by the upper portion of the last volution, which is rolled around the under volutions, as if around a longitudinal axis, and invested by a coating of enamel in the perfect or adult condition; the whole surface usually beautifully polished, and for the most part ornamented by spots, eyes, or zigzag markings; some few are grooved or ribbed on the external surface, and these have but little polish; aperture long, narrow, extending nearly the whole length of the shell, dentate on either side, effuse at the extremities; outer lip thickened and inflected.

Cypræa avellana. Plate III. fig. 45.

Found in the London Clay. The species are pretty numerous in a fossil state in the newer formations; they occur in the Crag, and in the *Calcaire-grossier* of Paris, Normandy, and Laugnan near Bordeaux.

The Cyprædiæ undergo considerable change of aspect in their progress from the young to the adult state, and in their unfinished condition may be mistaken for species of Bullæ and Ovulæ. They are oceanic shells, inhabiting the seas of the warmer portions of the globe, one species only being found in Europe.

Genus.—Calpurnus.—*Fleming.*

Generic Character.—Shell oblong, oviform, somewhat attenuated at both extremities with abbreviated canals; aperture longitudinal; outer lip smooth and thickened; columella with a notch at its base.

Calpurnus Leathesi. Plate III. fig. 37.

The Calpurnæ inhabit the ocean; one species occurs in the British seas, and the *C. Leathesi* is found fossil in the Crag at Walton.

This genus was instituted by Montfort for the reception of *Ovula Leathesi*, whose characters do not agree with those of the genus *Ovula.*

Genus.—Erato.—*Risso.*

Generic Character.—Shell ovate, more or less angulated, or conoidal, generally smooth, with a short, conical, distinct, and visible spire, the suture covered with enamel, and terminated in a sub-mammillated apex, last or body volution large, inflated; aperture linear; outer lip thickened, inflected, and denticulated within; the base slightly emarginate.

Eato Maugeriæ. Plate IV. fig. 4.

The shells of this genus are marine, and in form are intermediate between Cypræa and Marginella. There is only one living example in the British seas. Fossil species are found in the Coral and Red Crag formations.

Seven recent species of this genus are known, all of which are small shells; they have generally a few folds on the columella.

TRIBE II.—COLUMELLARIA.

Shell destitute of a canal at the base of the aperture, but provided with a more or less distinct subdorsal notch, and folds upon the columella.

Genus.—Volvaria.—*Lamarck.*

Generic Character.—Shell cylindrical, convolute; spire nearly hidden and depressed, terminating in a small blunt hardly salient apex; aperture narrow, extending the whole length of the shell, somewhat wider and truncated at the base; columella with three or four oblique folds near its base; outer lip denticulated.

Volvaria Acutiscula. Plate III. fig. 36.

The shells of this genus are known only in a fossil condition, and found in the Calcaire-grossier of Paris, Bordeaux, Grignon, and the London Clay at Hordwell.

Distinguished from the *Bullæ* by the plaits on the base of the columella, and by their transversely striated exterior.

Genus.—Marginella.—*Lamarck.*

Generic Character.—Shell oblong-ovate, smooth; spire short, in some species nearly hidden; aperture elongate, narrow, wider below than above, and slightly notched at the base; outer lip reflected, provided with a longitudinal varix of thickening; lower portion of the columella furnished with several folds or plicæ.

Marginella quadruplicata. Plate III. fig. 46.

Section 1.—Spire short, distinct; base of the columella with six plaits, the lower one largest. Marginella glabella is a type of the section.

Section 2.—Spire short, hardly visible, with some plicæ at the base of the columella. Type, Marginella perspicula.

The Marginellæ are marine shells. The only fossil species known is the M. quadruplicata, Plate III. fig. 46, and belongs to the latter section.

Genus.—Voluta.—*Linnæus.*

Generic Character.—Shell subovate, surface generally variegated with different colours and markings, for the most part covered with a thin, fuscous, membranous epidermis; spire

short, terminating in a papillary apex; aperture oblong; columella plicated, the lower plaits being the largest; base emarginate; destitute of an operculum.

Voluta lyra. Plate IV. fig. 1.

The variety of forms comprehended in the genus, render it necessary to constitute five subdivisions for their reception, viz.:—

SUBDIVISION I.—Papilla large and smooth.

Section 1.—Coronated.

Section 2.—Not coronated.

SUBDIVISION II.—*Vespertiliones;* papilla tuberculated.

SUBDIVISION III.—Papilla smooth, medium sized, and subacute.

Section 1.—*Ventricasiones*, or bellied species.

Section 2.—*Graciliones*, or slender species.

Section 3.—*Musicales*, or music volutes.

SUBDIVISION IV.—*Mammillares.* Mammillary species, with a mammiform apex.

SUBDIVISION V.—*Mitriformes.* Mitre shaped.

The volutæ, in a recent state, inhabit the seas of warm climates. They are met with, in a fossil state, in the formations above the Chalk, in the Calcaire-grossier of Grignon and Laugnan, the London Clay and Crag; and the *Voluta Lyra* has been found in the Cornbrash under the Chalk.

Genus.—MITRA.—*Lamarck.*

Generic Character.—Shell subcylindrical, elongated, generally covered with a thin horny epidermis; spire variable in length, but generally greater than the extent of the aperture; aperture longitudinal, elongated, notched at the base, and terminating in a very short canal; columella provided with a series of plaits, which are sharp at the edge, and the lower ones smallest; margin of the outer lip usually sharp: in other species it is somewhat thickened and crenulated, and even provided with an obtuse tooth at the upper part interiorly.

Mitra plicatula. Plate IV. fig. 2. *Mitra Dufrensi.* Plate IV. fig. 3. Both from the Paris basin.

The Mitræ inhabit the tropical seas; most of them in the Indian Ocean. They are found fossil in almost all the Tertiary formations.

The species are liable to considerable variations in external form; we have given representations of the most conspicuous of these.

Genus.—RINGICULA.—*Deshayes.*

Generic Character.—Shell small, ovate; spire short, terminating in an acute apex; surface smooth or spirally striated; columella callous and deeply plicated; outer lip thickened and reflected, with a deep notch at the base of the aperture.

Ringicula Ventricosa. Plate IV. fig. 12.

These are marine shells, and on that account are separated from the genus Auricula of Lamarck, in which they were formerly placed. Two living species only are known.

The fossils of this genus are met with in the Red and the Coral Rag formations.

Genus.—COLUMBELLA.—*Lamarck.*

Generic Character.—Shell oblong-ovate, invested with a thin epidermis; spire short; aperture elongated, contracted and narrow, usually about half the length of the shell, rather narrow and notched at the base, which is more or less emarginate, and ending in a very short canal; columella somewhat contracted in the centre, opposite the internal tumour of the outer lip, and denticulated at the base; outer lip thickened and tumid, and denticulate in the centre internally; in some species the tumid part is represented by a few strong projecting teeth. Said by Adamson to be provided with a small, slender, horny operculum.

Columbella nebulosa. Plate IV. fig. 5.

The Columbellæ inhabit the ocean. Fossil species are found in the Tertiary deposits of Italy. One species (*C. sulcata*, Wood's Crag Mollusca, Pl. II, fig. 2, *a* to *d*) has been discovered in the Red Crag, Walton, Naze, and a variety at Lutton. But this species is rather an aberrant form, connecting the genus with Nassa.

TRIBE III.—PURPURIFERA.

Shell with a short canal ascending posteriorly, or provided with an oblique notch at the base of its aperture.

SUBDIVISION I.—Shell with an oblique notch, directed backwards, and furnished with a canal.

Genus.—TEREBRA.—*Lamarck.*

Generic Character.—Shell greatly elongated, subulate; spire very long, consisting of many flat, gradually tapering volutions, terminating in an acute apex; body very small in proportion to the spire; aperture ovate, a little contracted above, with a short straight canal at the base; columella oblique, spiral, or twisted, frequently striated; outer lip thin and sharp at the edge; provided with a thickish, oblong operculum, which is somewhat pointed at the base, but not spiral.

Terebra plicatula. Plate IV. fig. 6.

The shells of this genus and those of *Turritella* resemble each other, but are easily distinguished by the form of the aperture, which, in the latter genus, is nearly circular, and are destitute of a canal, and the twisted columella of Terebra.

The Terebræ are oceanic shells, inhabiting principally the seas of Africa, India, and the West Indies. They occur fossil in the Newer Strata of Turin, Bordeaux, Piacenza, and in the London Clay.

It has been proposed by Blainville to form a new genus, under the name of *Subula*, from the more ventricose species, agreeing with *Terebra maculata;* but this is quite an unnecessary alteration.

Genus.—EBURNA.—*Lamarck.*

Generic Character.—Shell ovate or elongated, with a fine polished surface; outer lip simple; aperture longitudinal; emarginate at the base; columella umbilicated above, with a canal below the umbilicus.

Eburna glabrata. Plate IV. fig. 7. Found in the Chalk, Sussex. It is, however, doubtful whether this is a true Eburna.

Genus.—BUCCINUM.—*Linnæus.*

Generic Character.—Shell subovate, or ovate-conical, seldom elongated, subturreted; apex a little obtuse; spire of medium length, somewhat abruptly acuminate, but seldom of greater length than the aperture, which is suborbicular, or a little longer than wide, notched at the base, and hardly acute at its upper termination, where there is sometimes a small tooth-like process, formed by the thickening of the inside of the outer lip, with frequently a similar tooth opposed to it at the superior part of the inner lip, these enclosing a small sinus; outer lip rather acute at the edge, sometimes internally and transversely grooved, and in some instances with a dentated margin; columella smooth, frequently a little roughened at its inferior extremity; canal generally very short and straight; operculum horny and thickened.

Buccinum prismaticum. Plate IV. fig. 8.

The Buccina inhabit the African coasts, the British seas, and Northern Ocean. But few species have been found in a fossil state, and are chiefly met with in the Norfolk, Suffolk, and Essex Crag, some few occur in the London Clay and upper marine formations.

Although Lamarck has done much in distributing many of the Linnæan Buccina among other genera, still it would require considerable revision; many, with a lengthened canal, approach too nearly to *Fusus*, and those with a very short canal are nearly allied to *Purpura*, while others are so nearly connected with *Terebra*, that there is considerable difficulty in distinguishing them.

The *Buccinum undatum*, a common shell in the British seas, is the best type of the genus.

Genus.—NASSA.—*Lamarck.*

Generic Character.—Shell oblong, usually subturreted; spire generally of mediocre length, with an acute apex, or short, with an obtuse apex; aperture suborbicular, longer than broad, notched at the base; outer lip more or less thickened, sometimes provided with a small marginal appendage close to the upper part, and generally grooved or toothed internally; inner

lip much thickened, and, for the most part, spread over the lower region of the body in front, seldom extending to the base of the shell, and frequently provided with a small tooth at the superior part immediately within the aperture; columella spiral, its lower margin acute, and sometimes ending in a strong point, not unfrequently rough; canal very short, reflected, and never projecting beyond the base of the body volution. Furnished with a horny operculum.

Nassa reticulata. Plate IV. fig. 9. Found in the Tertiary formations in the neighbourhood of Nice.

The shells of the genus *Nassa* differ from those of *Cassis* in having mostly a longer spire, and a shorter aperture, which can hardly be called elongated; with a shorter canal, which is almost invariably attached to the back of the body; in the inner lip being less expanded, and in the varices never being formed until the shell is mature.

The Nassæ are marine shells, and inhabit the seas of almost all climates.

Most of the numerous species are grooved, granulated, tuberculated, or striated on their outside; in some few instances they are polished.

Fossil species are few, and are met with in the Crag, Greensand, London Clay, and its contemporaneous strata, in Italy and France.

Genus.—Dolium.—*Lamarck.*

Generic Character.—Shell subovate, extremely ventricose, approaching to globular; thin; more or less strongly costated transversely, covered by a thin horny epidermis; spire very short, with a semitransparent apex; aperture very large, straitened above, and terminating below in a short reflected canal; outer lip thin for the most part; in some species a little thickened, reflected and crenated at the edge.

Dolium nodosum. Plate IV. fig. 10. Found fossil in the Chalk, at Hurstperpoint, Sussex, and is supposed to be the only fossil species of this genus.

The shells of this genus inhabit the ocean, chiefly the tropics. Some of the recent species approach nearly in form to the Buccinea, but their canal not being reflected, distinguish them from the latter genus.

Genus.—Harpa.—*Lamarck.*

Generic Character.—Shell oval, ventricose; spire very short, with rounded volutions; body large, covered with longitudinal ribs, which are generally pointed above; aperture large, oblong ovàte, much expanded, and terminating in a notched base, which can hardly be called canaliculate; outer lip thickened, and a little reflected at the edge; inner lip reflected over the columella, united to the outer lip above, and terminating in a point below.

Harpa mutica. Plate IV. fig. 11. Found fossil in the *Calcaire-grossier* at Grignon, Bordeaux, and Volognes, and is the only fossil species known.

The Harpæ inhabit the ocean, and are all natives of the Indian seas. They are but few in number.

Genus.—Purpura.—*Bruguière.*

Generic Character.—Shell generally ovate, or oblong; spire short, mostly grooved, granose, or tuberculate, or externally spinose; aperture generally largely dilated, and ovate; margin of the outer lip usually sharp, and frequently toothed within, near the edge; emarginate at the base, where it is notched, and ending in a short canal; columella generally depressed, often internally acute at the edge, and terminating below in a sharp point; operculum horny, provided with a lateral nucleus, thinner on the margin next the columella.

Purpura tetragona. Plate IV. fig. 13. Found in the Crag near Ipswich.

The Purpuræ are oceanic shells, and in a recent state are very numerous, occupying a wide geographical range. The fossil species are, however, very limited.

Genus.—Purpuroidea.—*Lycett.*

Generic Character.—Shell turbinated; spire elevated, and not longer than the aperture, with a somewhat acute apex; volutions convex, nodulated in their middle, and the body one ventricose; the base truncated; aperture subquadrate, and acute above, widely but not deeply notched at the base, which is not recurved; columella curved and inflected at its base, which is rounded, pointed, and smooth; inner lip effuse, somewhat depressed in the middle, covering an umbilicus; outer lip thin, and a little sinuated.

Purpuroidea Moreausia. Plate IV. fig. 14.

The shells of this genus are peculiar to the Oolitic rocks in England, the Coral Rag of St. Michael, and the Ferruginous Oolite of Launoy. In England they have only been met with in the beds of planking upon Minchinhampton Common.

Genus.—Cassis.—*Bruguière.*

Generic Character.—Shell ventricose, gibbous, subtrigonal for the most part; body large; spire generally very short; aperture longitudinal, narrow; in some species nearly equal to the whole length of the shell, in others proportionally wider, (in which case the aperture can hardly be considered as elongated,) with a more produced spire; base of the aperture terminating in a short canal, which is abruptly reflected, and its inner margin acute; columella twisted, provided with transverse plaits, or rugose; outer lip usually inflected, and spread over the lower portion of the body, producing a flattened disk, reaching beyond the edge of the lower varix, and internally dentated; and, in many species, forming a varix at the completion of each volution. Not known whether it is provided with an operculum.

Cassis bicatinatus. Plate IV. fig. 15. Found in the Crag at Bawdsey, Sussex.

The species of this genus are numerous, they have either protuberances on the superior part of the volutions, and are decussated, cancellated, grooved and striated in various ways. They are oceanic, and inhabit the tropical climates, burrowing in the sand at a distance from the shore.

The fossil species are few, and these are found in the Tertiary formations.

Genus.—Oniscia.—*Sowerby.*

Generic Character.—Shell oblong-ovate, subcylindrical; broad above, acuminated below, and usually cancellated, ribbed, or tuberculated; spire generally short, terminating in an obtuse apex; aperture longitudinal, elongated, somewhat contracted above and below, with a very short canal at its base; outer lip thickened, numerously toothed on its inner edge, broadly reflected on the columella, and furnished with granulations; supposed to have an operculum.

Oniscia cithara. Plate IV. fig. 16. Found fossil at Belforte, Italy.

The Onisciæ inhabit the ocean. There are but few species in the genus, and these are tropical.

Genus.—Cassidaria.—*Lamarck.*

Generic Character.—Shell subovate, ovate, or oblong; ventricose; body very large; spire short; aperture longitudinal, narrow, terminating at the base in a recurved canal, which points upwards, when the shell is held with the aperture downwards; outer lip marginate, thickened, reflected, frequently dentated within; inner lip expanded, covering the lower portion of the body and columella, but detached from it at the base, immediately above the canal, which, in some species, is rough, granular, tuberculate, or rugose; outer surface generally grooved, tuberculated, and covered with a thin horny epidermis. Supposed to have an operculum.

Cassidaria carinata. Plate IV. fig. 17. Found fossil in the London Clay at Highgate Hill. Fossils of this genus are, however, very rare, and are met with only in the Tertiary deposits, such as the *Calcaire-grossier* of the Paris basin and Piacenza.

The chief difference between the shells of this genus and those of Cassis, consists in the beak being more abruptly curved than in the latter genus.

The Cassidariæ inhabit the oceans of the tropics, and the species are very limited in number.

Subdivision II.—Shells destitute of a regular canal.

Genus.—Caliendrum.—*Brown.*

Generic Character.—Shell oblong-ovate, acute; volutions deeply divided; aperture irregularly ovate, oblique, rounded above and contracted beneath; columella greatly reflected and undulous, destitute of a canal at the base; outer lip very broad, somewhat reflected, and smooth on the margin.

Caliendrum vittatum. Plate IV. fig. 18. Found in the Mountain Limestone at Bolland.

Known only in a fossil state. *Buccinum vittatum*, Phillip's Geology of Yorkshire, ii., plate 16, fig. 14.

COMPENDIUM OF LOGIC.

CHAPTER IV.

SYNTHETICAL SUMMARY—NATURAL DIVISION OF LOGIC—PART I.—IDEAS AND LANGUAGE—ARISTOTLE'S PREDICABLES AND CATEGORIES—PART II.—OF JUDGMENT AND PROPOSITION.

We now proceed to exhibit the deductions and rules of logic *synthetically*, that is to say, beginning at the elements of the science, and rising from the simpler to the more complex, until we arrive at the various forms of the syllogism, with its application to the art of reasoning, and to the detection of fallacies.

The *end* of logic has been defined, the discovery of truth; its *object*, the human understanding; its *subject*, all that we see, hear, perceive, or understand.

The operations of the mind immediately concerned in argument are three in number, and are called by logical writers—1st. Perception, or Simple Apprehension; 2nd. Judgment; 3rd. Discourse or Reasoning. It is not asserted that these are the *only* operations of the mind, but that they are its only operations concerned in argument. It belongs to the metaphysician to determine what may be the province of Memory, Imagination, &c.; Logic is concerned only with Reasoning.

Perception, or *Simple Apprehension*, is that act or condition or the mind by which it perceives, contemplates, or receives a notion of any object. The image or notion thus received into the mind, is called an *idea*. Perception, therefore, is to the mind what vision is to the eye, and is analogous to the perception of the senses generally. It is, however, quite distinct from that of the senses, for the mind may perceive or conceive ideas which cannot come through the senses. Life, honesty, time, eternity, virtue, and mental attributes generally, may be conceived in the mind, though not to be discerned by the senses; and we may perceive ideas of these, as well as of a horse, a river, a mountain, or any other visible or tangible object.

Judgment is that act of the mind by which it compares together two of the notions or ideas which are the objects of Perception, and, noting their agreement or disagreement, affirms or denies the one of the other. Thus, an idea of "distance" is onething perceived in the mind; our idea of "the fixed stars" is another; but finding that these ideas agree, or that the one belongs to the other, we affirm, as an act of the judgment, that "the fixed stars are distant."

Reasoning or *Discourse* is that act of the mind, by which we compare two or more judgments, and thence infer a third.

Language is the medium or instrument by which we express or communicate to others these intellectual operations, or their results, and by which it may be said that they are generally carried on in our own minds. How far we could reason without language is a difficult question, but not of much practical importance, seeing that our reasonings and ideas must always be expressed in language to render them of any value.* Language consists of words, which are the signs or marks of ideas, as these ideas themselves are the signs of the things or relations which they represent in the mind.

The expression of an idea in one or more words, is called a *term*. A term, therefore (or, in the technical language of logicians, *vox simplex*), expresses the result of the mind, acting in its first operation, Preception.

The expression of a judgment, that is to say, of the agreement or non-agreement of two ideas, is called a proposition, or, in the technical latin of logicians, a *vox complexa*. A proposition, therefore, expresses in words the result of the mind, acting in its second operation, Judgment.

Reasoning, the third operation of the mind, which consists in seeking and perceiving the agreement or non-agreement of two ideas by the comparison of each with a third, is expressed in words by an argument, which, when fully developed, is termed a *Syllogism*, or, in technical latin, a *vox decomplexa*.

Logic is accordingly divided into three parts: the first treats of Perception, or Simple Apprehension, embracing Ideas and Language; the second, of Judgment and Propositions; the third, of Reasoning and Syllogisms. We shall now give a summary of the art or science of logic in this systematic order, adding a Fourth Part on Fallacies, and a Fifth on Inductive and Deductive reasoning, as applied to the discovery of Truth; though, strictly speaking, both of these subjects are comprehended in the Third Part, under the general head of Reasoning.

Part I.
OF IDEAS AND TERMS.

The image or notion which the mind receives in the simple act of Perception, is termed an idea. Thus, when we perceive external objects, or think of qualities or attributes, or even when the mind is reflecting on its own internal operations, the result is the existence in the mind of certain corresponding ideas. Our notions of external objects perceived, such as of a man, a tree, a mountain, are frequently termed images. Inward ideas, on the contrary, such as our notions of thought itself, of hatred, spirit, hunger, love, &c., are termed simply ideas or perceptions.

THE FIVE PREDICABLES.

The nature of anything, whether actually, or only possibly existing, is termed its Essence or Being. A being, therefore, is considered as possible or as actual; and all our ideas with respect to being or essence, must fall within one or other of five classes or predicables, namely, Genus, Species, Difference, Property, and Accident.

Species is a term for a number of individuals agreeing in their whole essence or nature, and differing only in severalty, that is to say, in being merely different individuals of the same nature. Thus *man* is the species of Cæsar, Cicero, Newton, &c., all agreeing in the common nature of humanity, and differing only as individuals.

Genus is a term for a number of species, agreeing in a part of their nature or essence, but differing in that remainder which constitutes them several species. Thus *animal* is the genus of man and horse—beings which agree in part of their essential nature, in that which constitutes each of them an animal—but differ in another part of their essence—in that which constitutes the one a rational, the other an irrational creature.

Difference (*differentia*), is a term for that part of the essence or nature, which, in the distribution of a genus into its species, constitutes each species what it is, or forms what is commonly termed the *characteristic* of the species. Thus, rationality is the difference or characteristic of man, irrationality of beasts, &c.

A *Property* is a term for some quality or attribute, which, though not regarded as constituting primarily a part of the essence, is yet inseparably joined to it, and therefore belongs

* Archbishop Whately affirms that the process of Reasoning cannot be carried on *in the mind* without language—"And accordingly," he says, "a Deaf-mute, before he has been taught a language—either the finger-language or reading—cannot carry on a train of Reasoning, any more than a brute. He differs, indeed, from a brute, in possessing the mental *capability* of employing language; but he can no more make use of that capability, till he is in possession of some *system of arbitrary, general signs*, than a person born blind from cataract can make use of his capacity of seeing, till the cataract is removed. Hence it will be found, by any one who will question a Deaf-mute who has been taught language after having grown up, that no such thing as a train of Reasoning had ever passed through his mind before he was taught." The Archbishop then alludes, in a note, to the case of Laura Bridgeman, an American girl, who had been from birth, not only deaf and dumb, but also blind, although she was afterwards taught the finger-language, and even to read what was printed in raised characters. He remarks of this girl that, when alone, her fingers were generally observed to be moving, though the signs were so slight and imperfect, that others could not make out what she was thinking of, but if they inquired of her, she would tell them. It was also observed that, when asleep, and doubtless dreaming, she had her fingers in motion, being, in fact, talking in her sleep.

to every individual of a species. Thus, the faculty of laughing is one of the properties of humanity; freezing and boiling are properties of fluids.

An *Accident* is that which is contingently joined to the essence, and therefore may be wanting in some individuals of the species. Thus, the whiteness of the skin in Europeans, is logically termed an accident, by which they are distinguished from other races of the same species.

These are Aristotle's five Predicables, that is to say, the five classes, to one or other of which belong all our ideas respecting the *essence* of things, or that which constitutes things what they are. The terms by which they are distinguished have long been adopted into common usage, in the meanings which are here assigned to them, and therefore not only the logical student, but the general reader should remember them. Genus, Species, Difference (or Characteristic), and Property, are those most commonly used, the last being frequently employed to denote an Accident also, as above defined—that is to say, a contingent, as well as a necessary property.

Genus and Species are the two which signify classes; Difference, Property, and Accident mark out only distinctions.

A Species is a class of individuals; a Genus is a class of classes, or of species. The term genus is therefore the more comprehensive, as regards the amount of individuals embraced under it; but species is more extensive in its meaning, though less comprehensive in its application. Species includes the meaning of genus, together with the difference or characteristic: thus, to the word *animal*, which is the name of the genus, add the word *rational*, which is expressive of the difference, and this will give *rational animal*, which is the species *man*; to the words *rational animal*, add the accidents distinguishing any one individual, and you will have a still more extensive term, though limited now in its application to that individual alone —a term expressed or implied in a singular or proper name, as Nicholas, Plato, Alexander. Each of these names denotes *a rational animal distinguished by certain accidents which are peculiar to itself.*

Whately gives a good illustration of what may be termed the *gradation* implied in the words genus, species, and singular term. He says—"The impression produced on the mind by a singular term, may be compared to the distant view taken in by the eye, of any object (suppose some particular man), near at hand, in a clear light, which enables us to distinguish the features of the individual. In a fainter light, or rather further off, we merely perceive that the object is *a man;* this corresponds with the idea conveyed by the name of the species. Yet further off, or in a still feebler light, we can distinguish merely some *living object*, and, at length, merely *some* object; these views corresponding respectively with the terms denoting the Genera, less or more remote."

The allusion here to "less or more remote Genera" may be explained thus. The *algæ* are a species of the genus *vegetable;* but vegetables may be regarded as included in a higher or more remote genus, *organized beings*—a genus including also animals; these, again, are comprehended under a still higher genus, that of *created things* in general—a genus including animals, vegetables, and inorganic bodies. Thus we have, *algæ*, a species of the genus, vegetable; vegetable, a species of the genus, organized being; organized being, a species of the genus, created thing.

Some general terms, therefore, may become, in different uses, both a genus and a species. Whatever class we take as a species, the class immediately above it becomes the genus of that species, and *vice versâ*. Or, all the classes above it may be reckoned genera, more or less remote. Thus, in the preceding gradation, the genus most remote from the species *algæ*, is *created thing*. This, being the widest generalization we can make, never becomes a species, and is termed *Summum Genus*, or the highest genus. In like manner, a species so low in the scale of gradation that it cannot be made the genus of any other species, is termed *species infima**, or lowest species.

* It is important to know the meaning of such technical terms, which, originally borrowed from the schools, have become a part of our language, and often occur in works not strictly of a logical character. Here we may state, that from *genus* (plur. *genera*), are derived the words *general* and *generic;* from *species*, the analogous terms, *special* and *specific*.

THE TEN CATEGORIES.

"The necessity of an Enumeration of Existences, as the basis of Logic," says Mr. Stuart Mill, "did not escape the attention of the schoolmen, and of their master, Aristotle, the most comprehensive, if not the most sagacious of the ancient philosophers. The Categories, or Predicaments—the former a Greek word, the latter, its literal translation in the Latin language—were intended by him and his followers as an enumeration of all things capable of being named; an enumeration by the *summa genera, i. e.*, the most extensive classes into which things could be distributed, which, therefore, were so many highest Predicates, one or other of which was supposed capable of being affirmed with truth of every nameable thing whatsoever."

In the five Predicables stated above, *Being* is divided according to its essence; in the ten Predicaments or Categories, *Being* is divided into Substance and Modes.

Every being must be considered, either as subsisting in and by itself, and is then called a *substance*, or, as it subsists in and by another, and is then called a *mode*, or manner of being. Thus, a stone, a spirit, a body, a cloud, are termed substances; whiteness, length, roundness, sweetness, are termed modes.

Now, according to Aristotle, all the possible modes of being are comprehended in nine classes, and these, with the addition of substance itself, as the basis or ground of them all—or, in other words, Substance and its nine Modes—constitute the ten Predicaments or Categories of Aristotle. These are enumerated as follows, in Greek, Latin, and English:—

Ουσια,	Substantia,	Substance.
Ποσον,	Quantitas,	Quantity.
Ποιον,	Qualitas,	Quality.
Προς τι,	Relatio,	Relation.
Ποιειν,	Actio,	Action.
Πασχειν,	Passio,	Passion.
Που,	Ubi,	Place.
Ποτε,	Quando,	Time,
Κεισθαι,	Situs,	Situation.
Εχειν,	Habitus,	Possession.

This enumeration of the classes or categories, under which all our ideas, or rather the objects of all our ideas, may be ranked, is now universally acknowledged to be very imperfect —to be both redundant and defective. It has been, not unjustly, compared to a division of animals into men, quadrupeds, horses, asses, and ponies. *Relation*, for instance, includes Action and Passion; Place and Situation are nearly synonymous terms; while mental states or sensations, as hope, fear, taste, pleasure, &c., appear to be properly included in none of the categories mentioned.

This division has, therefore, been abandoned, and, according to the modern doctrine, Being (or whatever the mind can conceive) is first divided, as by Aristotle, into Substance and Modes, while modes are again divided into either essential or accidental, either absolute or relative, either intrinsic or extrinsic, and various similar subdivisions, which do not seem of much importance. But, briefly to explain what is meant by one or two of these divisions, we may state that, as a mode must depend for its existence on a substance, the latter is termed the subject of the mode, or that without which it could not exist. Quantity, shape, weight, &c., are said to be modes of the body; love, fear, anger, consciousness, &c., modes of the mind. An essential mode is defined to be, that without which its subject cannot have the same nature or essence, as fluidity in water, roundness in a ball, powers of perception in the mind; for take from water its fluidity, take from a ball its roundness, or take from the mind its percipient powers, and each of these substances or subjects will cease to exist as such. The ball, for example, will cease to be a ball, although its materials may exist in another form. An accidental mode, on the contrary, is such that the subject may be separated from it, and yet will continue of the same nature. Motion or rest, whiteness or roughness, are accidental modes of a sphere. An absolute mode is that which belongs to its subject without respect to any other beings; a relative mode is derived from the relation that one being bears to another. Thus, roundness and smoothness are the absolute modes of a ball: greatness and smallness in anything are relative modes.

These, and a variety of similar distinctions in modes, are generally enumerated in logical works, with much precision of detail and variety of illustration. We regard them as practically useless, and therefore shall relieve our readers from the trouble of pursuing them further. It is, however, highly important to obtain a satisfactory classification of all nameable things, and therefore we present the following from the work of Mr. Stuart Mill—a classification which appears the most simple and rational we have yet seen:—

"I. Feelings, or States of Consciousness.
II. Substances.
III. Attributes."

In one or other of these Categories, all nameable things may be included. Each of them is a *summum genus*, that is to say, the most extensive class of the kind.

1. *Feeling*, in the proper sense of the term, is defined by Mr. Mill as a genus, of which Sensation, Emotion, Thought, and Volitions, are subordinate species. *Sensation* must be carefully distinguished from the object which causes the sensation; our sensation of white from a white object, and likewise from the attribute whiteness, which we ascribe to the object in consequence of its exciting the sensation; our sensation of heat from the heat of the fire, by which the sensation is produced. *Emotions* are *affections* of the mind, as Love, Anger, Sorrow, &c. Under the word *Thought* is included "whatever we are internally conscious of when we are said to think; from the consciousness we have when we think of a red colour without having it before our eyes [which would produce the *Sensation* of red], to the most recondite thoughts of a philosopher or poet." *Volitions*, or acts of the will, result from the emotions or judgments produced by sensation or thought; but these *acts* of the will must be distinguished from the *actions* which they produce; the intention or resolution to move the arm is an act of the will, or a volition; the motion of the arm consequent on that volition is an action.

2. *Substances* are divided into Bodies and Minds. Body or matter is the external cause to which we ascribe our *sensations;* Mind is the percipient of these sensations. "As body," says Mr. Mill, "is the mysterious something which excites the mind to feel, so mind is the mysterious something which feels and thinks." Again,—"As bodies manifest themselves to me only through the sensations of which I regard them as the causes, so the thinking principle, or mind, in my own nature, makes itself known to me only by the feelings of which it is conscious."

Some philosophers have maintained that neither matter nor mind exists; and it must be acknowledged that no other proof of their existence can be given than our intuitive belief or *conviction* of their reality. All that we can know of matter is by its sensible qualities—its colour (or visibility), hardness (or impenetrability), magnitude, shape, &c. Take away these, and nothing appears to remain; so that we are utterly ignorant of the nature of matter itself—we know only its properties. This doctrine has been carried so far, that what are commonly termed atoms of matter have been viewed as merely *points of repulsion.* The mind is in like manner known by its thoughts and feelings only; of that itself which feels and thinks, we know nothing.

3. *Attributes* are commonly divided into Quality, Quantity, and Relation; but this we must regard as a very inadequate analysis—not much better, indeed, than the exploded categories of Aristotle. The *quantity* of anything, for instance, can only be measured or estimated by its *relation* to another in point of magnitude. All attributes may probably be classed in respect of *quality* and *relation* alone. Then, again, the latter may be subdivided into some of the Aristotelian categories, such as relation in time, relation in space, relation as active or passive, &c. But this is a subject which belongs to Metaphysics, rather than to the science of Logic; it has always been attended with much difficulty, and could not be discussed advantageously within the contracted limits assigned by the nature and objects of the present treatise.

CLASSIFICATION OF IDEAS.

Having treated of Being in general, and of the objects of Perception, namely, Substances and Attributes, of which our ideas are the *mental representatives*, we now proceed to consider and classify these ideas themselves.

Ideas are divided into three classes, according to—1, their origin; 2, their nature; and, 3, their objects.

1. *Considered with respect to their origin*, Ideas are sensible, intellectual, or abstracted. *Sensible*, or *corporeal ideas*, are those which are derived originally from our own senses; such are our ideas of tastes, colours, form, motion, &c. Sensation is the *origin* of these ideas; but after having felt or experienced the sensation, the ideas remain in the mind, and may be recalled by the power of recollection, when the bodies which produced the sensation have ceased to be present. *Intellectual ideas* are those which we derive from the consciousness of what passes in our own mind; as our ideas of fear, anger, doubt, thought, knowledge, &c. These are obtained directly by consciousness, but may be recalled by memory, and become the objects of perception, after the emotions, or feelings, or trains of reflection which suggested them have passed away. *Abstracted ideas* are those which we derive from abstraction, or from that faculty of the mind by which we are enabled to withdraw some parts of an idea from other parts, and thus to confine the attention to the parts withdrawn or abstracted; such are our ideas of essence, power, substance, space, time, virtue, cause and effect, order, subject, &c. Thus, we can put out of view all the corporeal or mental qualities of any particular human being, and think of him merely as a man, a Christian, a fellow-subject, a fellow-creature, or even as a mere numerical unit in the population.

2. *Considered with respect to their nature*, Ideas are either Simple or Complex. A *simple idea* is one which does not admit of division, and cannot be separated by the mind into two or more ideas; such are our ideas of heat, cold, sweet, bitter, hard, soft, yellow, thought, motion, &c. A *complex idea* is one which is composed of two or more simple ideas combined; as our idea of a tree, a mountain, a man, a triangle—each of which may be divided into as many simple ideas as the bodies or objects themselves contain parts or qualities. Complex ideas are subdivided into Collective and Compound. A *collective idea* is one which is composed of many ideas *of the same kind* joined together; such is our idea of a forest, a flock, a congregation of worshippers, a regiment, the Roman senate: a *compound idea* is one which is composed of things of different kinds, regarded collectively—as virtue, learning, empire, encylopedia, furniture.

3. *Considered with respect to their objects*, Ideas are Particular or Universal. A *particular idea* is that of which the object is only one thing, or an individual. If this individual or object be indeterminate, as when we say a man, or a river, in speaking of a single man or river, but not with particular reference to any individual of the class, it is termed, in the language of the schools, an *individuum vagum*,—an indeterminate individual. If the object or individual be pointed out, as when we say the Thames, the Mediterranean, Paris, Alexandria, &c., or *this* man, *that* house, *the* mountain, the *first* emperor of Russia, —in that case the particular idea is termed a singular idea. A *universal idea* is that of which the object is a rank or class of beings, partaking of a common nature, and spoken of in that capacity; as when we say, *man is sinful, the camel is useful*, we here use *man* and *camel* as expressive of the whole class to which they respectively belong; and that idea in our mind which either of the words represents, is a universal idea.

LANGUAGE—TERMS—DEFINITION AND DIVISION.

As ideas are the mental signs or pictures of the objects or attributes they represent, so words are the *signs* by which we express or convey our ideas to each other, and by which, as Whately remarks, "the operations of the mind are for the most part carried on by ourselves." Language, written or spoken, is the medium by which we *express* our *ideas.*

The words of which language consists are mere arbitrary names, having no natural connection either with the ideas which they are employed to signify, or with the things which are the objects of those ideas. There is, indeed, a *natural* language expressive of certain emotions, but as a general rule there is no natural connection whatever between words and their meanings. Thus there is evidently no affinity between

the sounds tree, city, comet, love, admiration, yellow, beauty, virtue, and the objects, emotions, or qualities which these sounds represent.

Terms.—One or more words employed to express an idea or simple perception, is called a *term.*

A *simple term* is that which expresses an idea in one word, as Cæsar, white, anger, &c. A term is said to be *complex* when more than one word is used to signify one thing or idea, as "the luminary of day," "the last of the Cæsars," "the man who invented the art of printing."

A *categorematic* word is one that is capable of being employed by itself as a term. Adverbs, prepositions, conjunctions, &c., (as "truly," "with," "for," "by,") cannot be so employed, as not conveying by themselves any idea; such words are called *syncategorematic,* (*συν, with,* and *κατηγορεω, to predicate,*) because it is only *with* some other word that they can be *predicated* of anything. All the cases of nouns, except the nominative, fall under this latter class.

A *positive* term is one which implies the presence of any being or substance, as life, knowledge, the value of learning, &c. A *negative* term implies the absence of anything, as non-existent, invisible, uncertain, inconclusive. A *privative* term expresses the absence of something which might be conceived to be present, or which, by its absence, implies an imperfection, as blindness, dumbness, mutilation. We can say "a blind man," but not, in philosophical language, "a blind stone."

Some terms which appear to be negative, are really positive. Thus, the word *unpleasant* implies more than the mere absence of pleasure—it expresses the *presence* of a certain degree of pain or discomfort. So with the words *disagreeable, inconvenient, unwelcome,* &c.

A *connotative* term is one which denotes a subject, and implies an attribute; a *non-connotative* term is that which denotes a subject only, or an attribute only. "Thus," says Mr. Mill (who attaches very great importance to this distinction), "John, or London, or England, are names which signify a subject only. Whiteness, length, virtue, signify an attribute only. None of these names, therefore, are connotative. But *white, long, virtuous,* are connotative. The word *white* denotes all white things, as snow, paper, the foam of the sea, &c., and implies, or, as it was termed by the schoolmen, *connotes,** the attribute *whiteness.* Proper names are not connotative: they denote the individuals who are called by them; but they do not indicate or imply any attributes as belonging to those individuals." The word *man* is connotative, for when we apply it to an individual, as *this man,* the term implies or connotes that he possesses the attributes of humanity.

A *singular* term is that which applies to one individual only, as John, this river, that territory, the inventor of gunpowder. A *general* or *common* term is the name of a class, and may be affirmed of each individual of that class, as man, horse, mountain. A *collective* term is one which can be predicated of a class or multitude of individuals, but not of each separately, as a regiment, a troop, a multitude, the human race.

Concrete and *abstract,* are words which express another important distinction in terms, and one which is by no means confined to logical treatises. A *concrete* term is a name which either *de*notes or *con*notes a *thing;* an *abstract* term is a name which only denotes an *attribute.* Thus stone, table, house, are names of things, and are concrete terms. White, hard, foolish, ambitious, are words which connote things or persons possessed of these attributes, and are likewise concrete. Whiteness, hardness, folly, ambition, denote only the attributes themselves, abstracted from the things or persons possessing them, and therefore are called *abstract* terms. These are often erroneously confounded with *general* or *common* terms, the proper definition of which is given above.

A *relative* term denotes an object, considered as a part of a whole, or viewed in relation to another object, as base, summit, father, son, rider, commander. An *absolute* term denotes an object considered as a whole, and without reference to any other object, as tree, mountain, number. *Man* is an absolute term, corresponding to the relatives, father, son, officer, &c.

* "Notare, to mark; *con*notare, to mark *along with,* to mark one thing *with* or *in addition to* another."

Univocal and Equivocal.—Terms have been further distinguished by logicians, into univocal and equivocal. *Univocal* words, it has been said, are those which signify only one thing or idea, and are never applied to any other, as the words, *book, bible, fish, house,* &c. *Equivocal* words are those which are applied to signify two or more different kinds of things or ideas, so as to cause an ambiguity which is intended. Thus, the word *head* has been given as an example of an equivocal word, signifying either the head of a nail or of an animal—two very different things certainly; and, as another example, the word *post,* which may be either a piece of timber, or a swift messenger. These, however, as Whately remarks, "are not, strictly speaking, divisions of *words,* but divisions of the *manner of employing* them; the same word may be employed either univocally, equivocally, or analogously; either in the first intention or in the second. The ordinary logical treatises often occasion great perplexity to the learner, by not noticing this circumstance, but rather leading him to suppose the contrary." Mill makes a similar remark:—"In reality," he says, "an equivocal or ambiguous word is not one name, but two names, accidentally coinciding in sound. *File* standing for an iron instrument, and *file* standing for a line of soldiers, have no more title to be considered one word, because written alike, than *grease* and *Greece* have [or *one* and *won*], because they are pronounced alike. They are one sound, appropriated to form two different words."

This distinction in the manner of employing words is, however, highly important; it forms not only the basis of all kinds of puns, and figurative or metaphorical expressions, but of a great many fallacies which easily impose on an audience not particularly conversant with verbal subtleties. Almost all words have different shades of meaning, coming down from their *first intention,* or primary signification, through a variety of applications, until they appear in a totally different sense from that which they originally imported. Thus, we speak of the *vault* of heaven, the *atmosphere* of the political world, the *face* of a clock, the *rage* of the sea, the *fury* of the storm, the *foot* of a mountain, the *wing* of an army, a *brilliant* action.

Definition.—From the fact that so many words are *equivocal,* that is, admit of being used in different senses, it often becomes a matter of importance, either to explain the meaning of a word when obscure, or to state the precise sense in which it is used. This process is termed *Definition,* a word which is itself defined, as used in logic, to signify "an expression which explains any term, so as to *separate* it from everything else."

Definitions have been divided by logicians into *Nominal* and *Real.* A nominal definition explains merely the meaning of the term defined; a real definition explains the nature of the thing signified by that term. A nominal definition, or definition of a word, may be made by a more known word, by a negation of the contrary, a translation of the word into another language, or a grammatical explanation of its meaning: thus, a sphere may be defined a globe; oval, what has the shape of an egg; opaque, not transparent, &c. Definition of a *thing,* is the declaration of its nature, and is made by its genus, by its difference, by its properties, and occasionally by the enumeration of what are termed its accidents. Thus, *man* may be defined a "rational animal, endued with speech." Here, "animal," is the genus; "rational," is the difference (or characteristic) by which man is distinguished from other species of the genus animal; "endued with speech," is a property belonging to the whole species.

Sometimes a Nominal and Real definition may coincide. Thus, in defining mathematical *terms,* as a point, a line, a circle, we define also the things themselves. In this case, however, it must be stated whether the words are used in their strict mathematical sense.

"Logic," as Archbishop Whately remarks, "is concerned with Nominal definition alone; with a view to guard against *ambiguity* (or several meanings) in the use of terms. To ascertain fully the various properties [that is, the *real* definitions] of animals and vegetables, belongs to Physiology; of metals, earths, &c., to Chemistry; and so on with other things."

Division.—Division, in the common meaning of the word,

is the distribution of a *whole* into its parts. *Logical division* is different from this; it may be defined "the distinct or separate enumeration of several things signified by one common name." Thus, in the common sense of the word, a tree may be divided into root, stem, branches, and leaves; but neither of these parts separately can be termed a tree: in the *logical sense*, the genus, *animal*, may be divided into man, beast, bird, fish, reptile, insect, and these again subdivided into individuals, each of which is still termed an animal. An *individual* is so called because it is incapable of logical division—it is *indivisible* in the logical sense. Thus, we can divide the genus, *vegetable*, into different species, and each of these species into *individuals;* but, as the latter term implies, we can proceed no further in this kind of division.

The rules commonly given for a strict logical division are three:—1st. Each part taken singly, or any number of them, short of all, must contain less than the whole. 2nd. All the parts taken collectively, must contain neither more nor less than the whole; and we must therefore be careful to ascertain that the *summum genus* may be predicated of *every* term placed under it, and of nothing *else*. 3rd. The several parts of a division ought to be opposite or distinct, *i. e.*, one part must not contain another: thus, it would be highly improper to divide the *genus*, "Christian," into Protestant, Roman Catholic, Presbyterian, &c., for Presbyterian is not opposed to Protestant, but is contained under the term. To avoid what are termed *cross-divisions*, or such that the parts are contained in one another, a certain *principle of division* must be kept in view. Nothing but confusion could arise from a division of the genus, "Briton," into liberals, conservatives, churchmen, dissenters, chartists, and infidels; for some of these classes may be contained in some of the others. Such a division is on two principles, the one political, the other religious, and these must be kept separate to make the division a good one for any purpose. In every division, the principle on which it is made, if not positively stated, ought to be carefully kept in view and followed out.

Part II.

OF JUDGMENT AND PROPOSITION.

As the result of the mind, acting in its first operation, Perception, is a simple idea, expressed by a term, so the result of the mind, acting in its second operation, Judgment, is the perceiving the agreement or non-agreement of two ideas; and the expression of this act of the Judgment, in words, is a sentence, which is termed, *logically*, a Proposition.

NATURE AND PARTS OF THE PROPOSITION.

A Proposition, therefore, is *Judgment expressed in words.* It is a sentence, in which something is affirmed or denied of some other thing or person; as, "Gold is a precious metal," "No man is blameless." In these examples, the idea of "metal" agrees with the idea of "gold," and is therefore affirmed of it; the idea of "blameless" does not agree with our idea of "man," and is therefore denied of him.

A proposition (as formerly explained) is composed of three parts, namely, the Subject, the Predicate, and the Copula. The *subject* of a proposition is that of which anything is affirmed or denied; thus, *gold* is the subject of the proposition, "Gold is a precious metal." The *predicate*—a precious metal—is that which is affirmed or denied of the subject. The Copula is that which connects the subject and predicate, and is expressed by *am, is, are,* or some other part of the verb *To be.*

In some propositions, the copula or subject is not distinctly expressed, but is always understood, or implicitly contained in the sentence: thus, when we say, "the sun shines," "the trees grow," "I write,"—these are complete propositions, equivalent to "the sun *is* shining," "the trees *are* growing," "I *am* writing." In Latin and Greek, a single word is often a complete proposition, as (in Latin) *adsum*, "I am present." The laconic epistle which Julius Cæsar sent to the Roman Senate from Gaul, contained three complete propositions in as many words—*Veni, Vidi, Vici,* "I have come, I have seen, I have conquered;" *i. e.*, in the regular logical form, "I *am* having-come, I *am* having-seen," &c.

Such expressions as, "I am," "the world is," "there are wonders," (or "wonders are,") seem, on the other hand, to want the predicate. But this apparent anomaly arises from the fact that the verb "to be" is equivocal, or has two meanings, in the one of which it acts as a mere connecting verb, to signify that one thing is affirmed or denied of another; in the other sense, it signifies "to exist." The latter is its meaning in the examples given above, which, in a strictly logical form, would stand thus—"I am existent," "the world is existent," "wonders are existent."

That the verb "to be," employed as a copula, does not always signify *real existence*, may be inferred from such examples as the following:—"Ghosts *are* imaginary beings," "The phœnix *is* a bird fabled by the poets to have risen, with renovated youth, from its own ashes."

The copula, as such, has no relation to time, but expresses merely the agreement or disagreement of two given terms. When time or tense is an *essential* element in the question, it properly belongs to the predicate, as when we say, "this man *was* rich," the expression is equivalent to, "this *is* a man formerly-rich."

Sometimes the predicate is placed first in the proposition, as, "Great is Diana of the Ephesians," "In Egypt there are many pyramids," "It is the part of a wise man to live according to nature." These propositions, in their regular form, would stand thus:—

Subject.	Copula.	Predicate.
Diana-of-the-Ephesians	is	great.
Many-pyramids	are	existent-in-Egypt.
To-live-according-to-nature	is	the-part-of-a-wise-man

DIFFERENT KINDS OF PROPOSITIONS.

Propositions are divided according to their Substance, their Quantity, Quality, and Composition.

I.—Propositions, according to their Substance, or considered merely as *sentences*, are divided into Categorical and Hypothetical. A *categorical* proposition asserts simply and absolutely that the predicate does, or does not, apply to the subject, as, "Man is not made to mourn," "The Bible is filled with evidences of its Divine origin." A *hypothetical* proposition (sometimes called compound) is one in which the affirmation or negation is made under some condition, or with some alternative; as, "If the conflagration be not extinguished, it will destroy the city;" "Either Mohammed was a prophet, or the Koran is an imposture."

Hypothetical propositions are, therefore, subdivided into two kinds, Conditional and Disjunctive. The first of the preceding examples is that of a *conditional* proposition, denoted by "if," or some such word; the second example is that of a *disjunctive* proposition, denoted by the words "either" and "or." The term "hypothetical" (meaning a case supposed) is sometimes strictly confined to those of the former class.

Categorical propositions are, in like manner, subdivided into Pure and Modal. A *pure* categorical proposition asserts *simply* or *purely*, that the subject does, or does not, agree with the predicate; as, "Industry with prudence will lead to riches," "Charles I. was condemned to death by his subjects." A *modal* proposition asserts in what *mode* or *measure* the predicate agrees with the subject, as, "Industry with prudence will *probably* lead to riches," "Charles I. was *justly* [or *unjustly*], *wisely* [or *unwisely*], condemned to death by his subjects."

II.—Propositions, according to their Quantity, are Universal or Particular. A *universal* proposition is that in which the predicate is said of the *whole* of the subject, as, "All animals are mortal," "Every star is an inhabited world," "No coward is respected." A *particular* proposition is one in which the predicate stands only for a *part* of the subject, as, "Some animals are docile," "Every world is not inhabited," "All good men do not prosper."

In universal propositions, the subject is said to be *distributed*, as standing for the whole class, or as being such that the predicate is either affirmed or denied of the whole class; in *particular* propositions, the predicate agrees or disagrees only with a part of the subject, which is, therefore, not distributed. "Every world is not inhabited," means, that the predicate "not-inhabited," may be affirmed of *some* worlds.

In dividing propositions according to Quantity, logicians have enumerated also Singular and Indefinite propositions, both of which, however, are really included in the twofold division already mentioned.

A *singular* proposition, for example, is that of which the subject is either a proper name, or a common (or general) term, with a singular sign, as, " *Galileo* discovered the telescope," " *This man* is worthy of all honour." Now, in each of these cases the subject is an *individual, i. e.*, it cannot be divided according to the logical sense, and therefore the predicate is justly regarded as affirmed of the whole of the subject. A *singular* proposition is therefore a *universal.*

A proposition is termed *Indefinite*, when no sign or expression either of universality or particularity (as *all, every, some, many*) is prefixed to the subject. But such propositions, though indefinite in form, must either be particular or universal. Thus, when we say, " Man is mortal," " Planets move round the sun," we evidently mean that "*Every* man is mortal," and " *All* planets move round the sun;" when we say that "Clothes are essential to comfort in a cold climate," we evidently mean "*some* clothes." In this case, the quantity of the proposition is ascertained by the *matter, i. e.*, the nature of the connection between the extremes. But such propositions are merely elliptical in form; they are either universal or particular in all cases. It is, therefore, improper to regard *indefinites* as a separate and distinct class of propositions in respect of quantity. The name or term is convenient, as marking out a certain elliptical form in which propositions are often expressed—a form which may often be employed to conceal fallacies; and therefore, where any obscurity exists, every proposition (not a singular term) ought to be tested and *stamped* as to its quantity, by one or other of the words, *all, every, some*, &c., being prefixed to the subject.

III.—Propositions, according to their Quality, are either Affirmative or Negative. This applies to the " quality of the expression." Divided according to the " quality of the matter," they are either *true* or *false;* but in logic, the quality of the matter—the truth or falsehood of a proposition—is considered as *accidental*, and the quality of the expression as *essential.* Logic does not undertake to determine the truth or falsehood of propositions, but teaches how to reason correctly from any propositions whatever, whether true or false. The " quality of the expression" is, therefore, the essential point in logic; and, in this respect, propositions are, as we have stated, either Affirmative or Negative. A proposition is *affirmative*, when the predicate is affirmed of the subject, as, " Hydrogen gas *is* the lightest substance in nature;" when the predicate is denied of the subject, the proposition is negative, as, " Chemistry *was not* known to the ancients."

The affirmation or negation properly belongs to the copula, *is* or *is not, are* or *are not*, &c., although the expression implying the negation is often prefixed to the subject, and hence, sometimes, arises a slight ambiguity. For example, " No truly brave man is cruel," is a negative proposition, and may be resolved into the form, " A truly brave man *is not* cruel." But, " Not to despair, is to conquer," is an affirmative proposition, for in this case the negative cannot be thrown into the copula.

Hobbes, and some other writers, have tried to make all propositions affirmative, by looking on the very negation itself, in what are called negative propositions, as a part of the predicate. Thus, in the proposition, " Merit is not always rewarded," Hobbes would have made "*is*" the copula, and "*not-always-rewarded*" the predicate; whereas, by the majority of logical writers, "*is-not*" is reckoned the copula, and "*always-rewarded*," the predicate. Though Hobbes aimed at simplification in thus reducing all propositions to an affirmative form, the effect of attempting to apply his system in practice involves confusion and difficulty, while it is an evident departure from the common-sense view of the subject. The basis of Aristotle's Dictum is the *agreement* or *non-agreement* of the subject with the predicate, which relation is naturally expressed by a positive or negative copula, as the case may be.

The opposition and conversion of Propositions will be treated in next chapter.

CHEMICAL MANUFACTURES.

INTRODUCTION.

The words *Chemist, Chemistry, Chemical*, &c., are associated with widely different meanings, in the minds of different persons. Some think that the only real chemist is one who keeps a " doctor's shop," wears a clean white apron, stands behind a nice mahogany counter, and dispenses his pennyworths of salts, pills, and magnesia. Others, knowing or hearing that crucibles, retorts, alembics, and other working apparatus, are used by the practical chemist of present days, and *were* used by the alchemist of earlier times, and learning also that there are in chemical operations certain curious transformations of liquids into opaque or transparent solids, metals into vapour, &c., entertain an idea that there must be something mysterious about chemistry, and that a chemist must be a sort of Dr. Faustus, a " cunning man," who sees farther than other people. A third class, better informed than the others, have an acquaintance, more or less general, with the great chemical truths developed by such men as Priestley, Lavoisier, Black, Dalton, Davy, Gay-Lussac, and Faraday; but, regarding chemistry in a purely scientific point of view, they are scarcely prepared to rank it as connected with one of our great branches of national manufacture.

When the matter is viewed, however, a little steadily, and is stripped of certain parts which do not properly belong to it, we can form a tolerably exact notion of the proper acceptation of the terms employed, and how it arises that reputed magic, mystery, science, manufacturing art, and shopkeeping, become mixed up in such an incongruous manner.

In the first place, it will be well to bear in mind that alchemy was the parent of modern chemistry, bearing some such relation to it as astrology bore to astronomy. The astrologer studied the movements of the planets and stars, under the idea that they had an influence over his destiny in this life, and that possibly he might obtain thereby a foreknowledge of what this destiny was to be: the search was a fruitless one, so far as regarded the immediate object in view; but he *did* observe the movements of the planets and stars, and thus accumulated a knowledge of a large number of facts which have been valuable working tools to astronomers of later times. In like manner the alchemist, entertaining a crude notion that coarse cheap metals might be transmuted into gold, set to work to discover the agency whereby this might be brought about; fortunes were wasted, families ruined, and heads made crazy, without attaining the object in view; but many curious facts were collected, in relation to the chemical action of different substances on each other, which have rendered great assistance to the more rational chemists of later ages.

We thus get rid of the confusion arising from associating chemistry with the dark and mystic proceedings of alchemy: we have only to consider that alchemy was an early and imperfect stage of chemistry; the mutual action of various substances on each other being studied—not, as in modern chemistry, for a practical and attainable object, but for an object which is now known to have been unattainable.

Next may be explained away the vagueness of association between chemistry and the retailing of medicines. Before the Reformation, there were no recognised professors of the healing art in this country; the monks and the alchemists being, in fact, almost the only doctors. The former laid claim to supernatural aid in the preparation of medicines; while the latter, not content with trying how to make gold, sought for a universal specific which should cure all ailments whatever. The grocers', or, as we should now call them, the chandlers' shops, were supplied with the few drugs then used as medicines, and the shopkeepers were wont themselves, occasionally, to act the part of doctors, and prescribe medicines for the ailments of their neighbours; while the barbers took to themselves the office of drawing teeth, letting blood, and performing the simpler kinds of surgical operations. But about three centuries ago the College of Physicians was established, with a view of bringing the whole circle of medical operations under control; the selling of drugs, too, was afterwards separated from the

selling of groceries. The *apothecaries*, to whom the drug department was intrusted, gradually assumed the privilege of attending patients, and also claimed the exclusive right to sell medicines; but they could not retain both privileges, and hence arose another class still, the *chemists and druggists*. These latter, considered simply as shopkeepers, are not necessarily supposed to know what medicines are suited to certain diseases; nor, on the other hand, are they simply retailers: as druggists, they sell in small quantities what they purchase in larger bulk; and as chemists or pharmaceutists, they study the means of preparing a mixed medicine from simpler chemical materials; requiring a certain knowledge of chemistry to effect this, but leaving to the physician or the apothecary the decision of the fitness of the medicine for the disease which it is intended to cure.

It will perhaps, therefore, clear up matters a little to say, that if the proprietor of one of these shops gives advice as to the treatment of any ailment, he does so as an *Apothecary;* if he sells a medicine, such as rhubarb, or salts, in the same state as that in which he bought it, but in smaller quantity, he does so as a *Druggist;* but if he prepares a pill, or mixture, or a compound medicine from different elements requiring different chemical modes of treatment, he does so as a *Chemist*, or a *Pharmaceutist*, or (to use the more convenient French term) a *Pharmacien*.

But the proper acceptation of the word Chemist has yet to be considered. The pharmaceutist does not *discover* the chemical properties of bodies; he *applies* them, when discovered, to make numerous compounds. The real chemist, the man to whom the appellation in its highest sense is given, is he who discovers the great laws of chemical affinity, of definite proportions, of fusion, ebullition, vaporization, combustion, composition, decomposition, and all the many phenomena of a kindred nature. He does not, like the alchemist of old times, carry on his researches for a visionary and impracticable end; nor, like the physician, does he practically apply chemicals and drugs as healing remedies; nor, like the pharmaceutist and druggist, does he make medicines according to prescribed rules, or sell them by retail; but he seeks to establish those great truths with respect to the composition of bodies, which may be available to every one; and it is thus that men like Davy, Liebig, Dumas, and Muspratt, have attained the lofty position which their names occupy.

One other aspect under which chemistry is talked of and studied is still to be noticed; namely, its connection with manufactures. What is a manufacturing chemist? What is the link which binds the science of chemistry with the industrial arts? These points are not difficult to answer. Many of the more important chemical compounds are so largely used in the arts, that nothing less than large manufacturing arrangements would be adequate to their production. Take, as an example, sulphuric acid (oil of vitriol): the scientific chemist studies the nature and composition of this acid, discovers that it is formed of two simple elements, detects the exact proportion in which these two elements exist in it, tries experiments as to its action on water and on various other bodies, and groups together distinct statements as to all the results which he is able to obtain; but he has not the facilities, nor is it a part of his object, to make this acid for sale. Again, the physician studies the effect of this acid, alone or in combination with other substances, on the human body; and the pharmaceutist studies the mode of bringing it practically into combination with other agents; but neither the one nor the other attend to the making of the acid itself. The manufacturing chemist takes this larger and more commercial part of the arrangement; and he therefore holds a middle place: being indebted to the scientific chemist for the discovery of the elements and properties of the substance to be made; and leaving to the physician, the pharmaceutist, the dyer, the calico-printer, and others, the study of the best modes of applying the substance, when made, to any practical purpose.

If these few explanations are borne in mind, they may perhaps help to remove some little ambiguity as to the meaning of words, by showing the different interpretations put upon the word "Chemist," and their relative bearings one on another.

The following chapters are intended to convey a general outline of the modes of manufacturing some of the chief chemical agents, as conducted in our own country in the present day. There are two reasons why the details will be limited to a few of the principal chemicals: 1st, because the space devoted to the subject is small; and, 2ndly, because, on account of a general analogy observable in the manufacturing processes, one process becomes an index to many others. It will be useful, however, to preface the details by a notice of some of the chief chemical laws or principles which govern the processes of manufacture.

The most beautiful and valuable of these laws is perhaps that of *affinity*. By this is meant a tendency in two or more chemical bodies to unite and form one compound substance, the tendency being stronger in some instances than in others: what this affinity really is, cannot be told; we know nothing more about its intimate nature than we do of gravitation: in both cases it is the *effect* which observers and experimenters regard, the agent itself being known only by the effects which it produces. If all bodies tended to unite with equal readiness, there would be no definitely compounded substance whatever, for every element would be strong enough to disturb every other, and all would be in confusion; but there is a kind of elective or preferential affinity, which prompts two bodies to combine together rather than either of them with a third, and this gives rise to some degree of stability in the compound substances with which we are familiar; because two bodies, when compounded together by the affinity existing between them, cannot be decomposed except by some agent having a stronger affinity for one or other of them. Hence it is one of the important objects of a scientific chemist to discover the relative strength of this affinity among a great many substances. It has been found, for example, that sulphuric acid unites more powerfully with lime than with magnesia; still more so with soda, and most powerfully of all with potash.

An immediate power of great value results from this elective affinity; for a manufacturing chemist, observing and acting upon these various degrees of strength, can produce one compound by decomposing another. A beautiful example of this will be explained in the body of the volume in reference to common salt: this consists of chlorine and sodium, but the two elements are not very strongly united, inasmuch as they can be separated by many different agents, and, by taking advantage of the different degrees of elective affinity, chloride of lime or 'bleaching-powder,' muriatic acid, carbonate of soda, and many other valuable bodies, may be produced mainly by the agency of common salt.

Another important principle is the difference of form which different bodies put on at the same temperature: some assume a hard earthy state, some a crystalline state, some a liquid, some a gaseous; and this is often made a means of separating the elements of a compound body. Water, for example, boils and passes off in vapour at a temperature of 212°, while spirit boils at a much lower temperature; and therefore, by keeping a mixture of the two at a lower temperature than 212°, the spirit may be in part separated from the water: this is, indeed, the principle of distillation, however conducted.

The crystalline arrangement, too, is a valuable one to the manufacturer. It often happens that when several elements are compounded together in a liquid, one or two of them may be separated from the rest by allowing them to crystallize; this may be effected when one part of the compound has a tendency to crystallize sooner than the others. There is a very pretty exemplification of this in the making of alum, which we shall describe in a future page.

This principle (the difference in the form of different bodies at the same temperature) exhibits itself in so many ways, that the chemical manufacturer avails himself of it in almost every step of his progress. Two vessels, for instance, may contain two liquids, each composed of two different elements, and both liquids may be clear and transparent; but in adding these two liquids together, three out of the four elements may combine and form a ternary or threefold compound, leaving the fourth to fall to the bottom of the vessel in a fine earthy state, so as to be easily separable from the liquid. In such case, the fourth, or isolated

element, has a less intense affinity or attraction for each and all of the other three, than they have for each other, and is besides of such a nature as to present a fine earthy or sedimentary texture at that temperature.

The relation which exists between heat and chemical elements is another great department of chemical science, which must be extensively known to the manufacturer before he can make his acids and alkalis, his salts and solutions. We are accustomed, in common life, to speak of all substances as being solid, liquid, and gaseous, each substance having some one of these forms definitely. So indeed they have, in reference to any one prescribed temperature: for instance, at a temperature of 130° tallow is a liquid, but wax is a solid; at 450° tin is a liquid, lead is a solid. But in taking a comprehensive and general view of the whole range of substances, there is reason to believe that the great bulk of them are susceptible of all the three forms, according to the heat which they contain. It is true that in some cases the attainable heat is never high enough, or the cold intense enough, to obtain these results; but *ice*, *water*, and *steam* will indicate our meaning as to the broad facts.

A manufacturing chemist has to make himself practically acquainted with the fusing point (which separates solid from liquid) and the boiling point (separating liquid from vapour) of a large number of substances; since it often happens that his only means of manufacturing one substance from another, consists in separating them at a particular fusing and boiling point.

Some very important points are involved in the grouping of chemical compounds into *acids*, *alkalis*, *oxides*, *salts*, &c.; forming, in fact, the very alphabet of many manufacturing processes. In the earlier times of chemistry, acid was the name applied to anything which was *sour* to the taste; but modern chemistry has greatly extended the application. They are, as now enumerated, generally but not always sour, having generally a great affinity for water, redden most vegetable blue colours, and combine readily with most alkalis, earths, and oxides of metal; some are solid, some liquid, and some gaseous; and nearly all of them contain either oxygen or hydrogen as one of the ingredients, every acid being a compound. Alkalis are also compound bodies, having several valuable properties, among which one is a strong tendency to combine with acids. Salts are the combinations of acids with earths, or alkalis, or metallic oxides, possessing properties often wholly different from those of the component ingredients; thus, sulphuric acid, a burning and powerful liquid, when combined chemically with the mild and inodorous substance magnesia, constitutes the peculiar crystalline 'Epsom salts,' a body essentially different in its properties from the substances of which it was made.

All these are points with which a manufacturing chemist must be well acquainted, since he has to avail himself of them in the process of manufacturing one substance from another. The complexity in the relations existing between different substances is greater than can possibly be conceived by those who merely view matters in their every-day phase; and yet this complexity must be reduced to something like order and regularity before practical rules can be deduced and laid down. It is indeed a startling fact, that all the objects which surround us on this earth; all that is within and upon the earth; the air which we breathe, and the birds which inhabit it; the waters, the rocks, the trees, plants, animals—all that can meet the eye and the ear on earth, whether living or lifeless, are made out of so few as sixty or sixty-two different substances! * Though there are millions of distinct objects, yet (so far as the present state of science has revealed) it does not appear that there are more than this number of different elementary substances from which they are formed; most of the bodies with which we are cognizant being compounded of some two or more of these elements.

To any one who has paid a little attention to chemistry, these broad facts are well known; but a little elucidation may be desirable for some readers. The greater part of these elements are metals; but of those which are not metals, four of the most important are oxygen, hydrogen, nitrogen, and carbon. Now these four, in their simple and uncompounded state, are very little known to us in every-day life; but when combined two or more together, they form a surprising number of well-known substances. Of these a few may be here enumerated:—

Oxygen and hydrogen	form	Water.
Oxygen and nitrogen	in various proportions	Atmospheric air.
" "	in various proportions	Laughing-gas.
" "	in various proportions	Aquafortis.
Oxygen and carbon		Carbonic acid.
" "	in other proportions	Oxalic acid.
Hydrogen and nitrogen		Ammonia.
Hydrogen and carbon		Street-gas.
Nitrogen and carbon		Cyanogen (a gas).
Hydrogen, nitrogen, and carbon		Prussic acid.
Oxygen, hydrogen, and carbon (according to the proportions)		Sugar, starch, alcohol, acetic acid, or vinegar, and many other vegetable products.
Oxygen, hydrogen, nitrogen, and carbon (according to the proportions)		Albumen, fibrin, gelatine, gluten, and many other animal products.

The permutations of numbers, which form the arithmetical amusements of many a schoolboy, are not more surprising in their amount, while they are far less important in practice, than those among the sixty-two elementary substances; and when it is considered that the skill of a chemist—whether of a theoretical chemist, who studies the laws of his subject, or of a manufacturing chemist, who avails himself of those laws in practice—depends mainly on the extent to which he is acquainted with these permutations, it will not appear surprising that chemistry is deemed a progressive science, always advancing beyond the point from whence we started, and yet always showing that there is an indefinitely extended region yet to explore.

CHAPTER I.

CHEMICAL MANUFACTURES IN GENERAL.

Of the countless articles which every-day life presents to us, coming more or less under the general denomination of chemical substances, some are prepared quite in a domestic way, with very few appliances of skill or implements; some are brought to a saleable form by the shopkeepers who sell them; some are sold nearly in the state in which they are procured from mines or other natural sources; while others require the arrangements and extensive resources of large factories. There are some, too, such as soap, street-gas, &c., which, although not usually classed among chemical manufactures, yet involve so many of the peculiarities of chemical combinations as to be nearly allied to the others. For all these reasons, a really strict selection of details for our present purpose will be quite impracticable; and we shall have accomplished the object intended if we succeed in giving a slight outline of some of the broader features of the subject.

Generally speaking, the chemical works, strictly so called, are those in which the more important of the acids, alkalis, and salts are made, such as sulphuric, nitric, and muriatic acids; soda in various forms, chlorine, alum, metallic salts, &c.; while other factories are designated from the kind of substance made, such as white-lead works, colour works, &c. But all of them are influenced both by political and by scientific events in a remarkable degree.

That such establishments should be affected by the current of scientific discovery is what may reasonably be expected, since every advance in our knowledge of the constitution of bodies is likely to work changes in the modes of producing those substances. But in what way political matters are found to bear on the question may not be so obvious. A few considerations will, however, tend to show the kind of connection between these apparently disconnected agencies. If a manufacturer prepares certain chemical substances (say) from sulphur; and if political, or diplomatic, or fiscal disagreements should occur between England and the country whence this sulphur is produced, then the manufacturer might be constrained

* For an enumeration of these elementary bodies, See Vol. II., p. 488.

to procure his sulphur from some other source, perhaps by a complicated process on one of the English ores of sulphur. Again, suppose the English government removes the tax previously imposed at a heavy rate on some article of abundant supply, such as common salt, then the manufacturer may be induced to employ this material as a fund whence he may procure acids or alkalis previously procured from a more expensive source. Now these are not merely supposed cases; they have actually occurred within the last few years, as we shall show further on; and they illustrate the kind of effect which legislative or political occurrences are calculated to produce on chemical manufactures. The imposition or the removal of an excise duty on a commodity of home production; the imposition or the removal of a customs' duty on an imported foreign product; the establishment or the cessation of commercial intercourse with a country richly provided with some commodity which we require in our manufactures; the concentration, in the hands of a few, of a commodity required by the many; the legislative enactments which occasionally give rise to a demand for a particular commodity at a particular time;—all or any of these may work great changes in the arrangements of an establishment where chemical manufactures are carried on, irrespective of the still greater changes which naturally result from scientific discoveries in chemistry.

Chemical manufactures, like most others on a large scale, are carried on chiefly in the midland and northern counties. In most instances the chemical works are situated somewhat beyond the precincts of a large manufacturing town, since they require more space than can conveniently be procured within a town, and are liable to give off vapours and gaseous products, which are better at a distance than in close proximity to dwelling-houses. They are also generally situated near seaports, for convenience of shipment. Glasgow, Newcastle-upon-Tyne, and Liverpool, are perhaps the three principal centres for this class of manufactures. With respect to Glasgow, Dr. Thomson, at the meeting of the British Association in that city in 1840, gave some interesting details respecting the chemical manufactures of the district. He alluded especially to the vast works at St. Rollox, in the northern suburb of the city, where the furnaces and buildings extend over an area of ground unparalleled, we believe, by any similar works, and where a giant chimney rises to a height exceeding the dome of St. Paul's by a hundred feet. The factory was first established as sulphuric acid works in the latter part of the last century; they were at first small in size, and have risen to their present state by slow degrees. Besides this acid, bleaching-powder, or chloride of lime, is made at these works, a material of vast importance in reference to many branches of manufacture. Soap and other articles are also made at St. Rollox. Dr. Thomson also alluded to the alum manufacture, for which there are two establishments near Glasgow; one of these we shall notice further on; while at the other, besides alum, is made prussiate of potash and prussian blue. In another chemical factory near Glasgow is made, among other things, bichlorate of potash, highly useful to calico-printers; in another, acetic acid and pyroxilic spirit are distilled from wood; in others iodine; so that, taking the whole of these collectively, Glasgow may be deemed one of the chief centres of manufacturing chemistry.

The neighbourhood of Newcastle, too, is deserving of attention in this respect. The busy Tyne exhibits along both its banks, all the way from Newcastle to Shields (a distance of seven or eight miles), a continued succession of factories—here of glass, there of coarse pottery; at other spots, of chemicals, of lead, iron-works, oil-mills, engine-factories, and others, which tend to swell the importance of this bustling and thriving neighbourhood. Of these seats of manufacture, the chemical works are the most conspicuous, from the enormous height of their chimneys. No other factories or works have such lofty chimneys as chemical works, because no others give forth so many gaseous products likely to be of a deleterious character. In some of these instances (as we have just intimated) the chimneys considerably exceed St. Paul's Cathedral in height. In past times many of the chemical works were regarded (and correctly so) as pests and plague-spots, bringing desolation on all the vegetable products near them blasting the trees, and stunting the growth of almost every kind of field and garden produce. Numerous were the disputes between the various parties on these points; and an avowed good was, in this respect, always accompanied by an equally avowed evil. But modern research has wrought surprising changes in this respect. Every year adds something to the list of processes whereby a deleterious gas, previously sent forth into the atmosphere, becomes a source from which other and valuable products are derived; and it is scarcely too much to expect that such improvements will gradually be made, as to render the lofty chimneys less and less necessary—leaving them as memorials of a past and less skilful state of the manufacturing arts.

The Tyne separates Newcastle from Gateshead, the latter being to the former what Southwark is to London; and at a distance of a mile or two eastward from Gateshead is one such chemical work, which may be regarded as a type of the rest. The works occupy a position between the South Shields Railway and the river; and like most places in the neighbourhood, have abundant means of intercourse with the great central depôt, Newcastle, by cheap railways and still cheaper steamboats; and this facility, together with railways running along both banks of the Tyne, gives rise to an incessant and extensive intercourse.

On approaching the works, it is soon evident that they are of the class where a large number of buildings are spread over a great area of ground, rather than exhibiting one huge building, such as is often seen in the cotton districts. The buildings are of various sizes and shapes: some lofty, some shallow; some long and broad, others nearly square; some exhibiting within dry and dusty processes, others heat and vapour, others vessels and liquids; one with a lofty and well-proportioned chimney, others with chimneys of more humble dimensions. Narrow passages and square courts separate the different buildings.

Common *sulphur* and common *salt* are now the two great agents in the production of the chemicals in most familiar use. Sulphuric acid, or 'oil of vitriol,' chloride of lime, or 'bleaching-powder,' muriatic acid, or 'spirit of salt,' the soda-ash employed by glassmakers and soapmakers, the common soda employed in washing—all result from certain modes of applying one or other of these cheap and abundant substances; and these are precisely the commodities most generally made at chemical works. Nothing can more beautifully illustrate the general character of chemical composition and decomposition, than the steps by which one substance becomes transformed into another, as developed at a chemical work: the production of an acrid and poisonous body from harmless ingredients; the production of a liquid from two gases, or of a gas from two liquids; the generation of colour from the mixture of two colourless bodies; the transformation of an opaque earth into a colourless crystal;—these and analogous phenomena are constantly presented during the progress of chemical manufactures.

Sulphur and salt being thus two of the most valuable sources of chemical commodities, it may be well to devote a chapter to them in their individual form, before tracing their subsequent transformations. These will, therefore, be the subject of the next chapter.

PLAN FOR WORKING A FOOT-LATHE.

The following plan has been suggested for working a foot-lathe with more ease than by the method generally used. The standards have two bosses cast on the back legs, through which pass the centre pins, on which the crank revolves at a distance of 4 inches from the centre line of the lathe. By this contrivance the driving wheel is placed out of the way. On the front legs, a distance of 3 inches from the ground, a parallel bar passes, secured with nuts at each end. On this bar is placed the treadle, in form of the beam of a marine steam-engine; and, working in a similar way, to the inner ends are bolted two connecting rods, having forked ends for the purpose. The other ends of the connecting rods have straps, brasses, gibs, and keys, and are connected to the crank. On the outer ends of the treadles is placed the foot-board. The length of the treadles is 14 inches. In working this lathe the treadle gives motion to the crank in an upward direction, instead of the ordinary way, pulling it down with the whole strain on the crank pins.

ON SOME REMARKABLE PROPERTIES OF WATER AND OTHER FLUIDS,

AND THEIR CONNECTION WITH STEAM-BOILER EXPLOSIONS.

A Lecture, read before the Members of the Royal Manchester Institution.

The subject of this lecture is of so interesting a nature, and of such great importance to the engineering world, that we feel a more than ordinary degree of pleasure in laying the report of it before our readers, being well assured that the practical application of the theory therein laid down, will be attended with an extremely beneficial result.

The lecturer commenced with a few preliminary remarks upon the relation which subsists between the *philosophy* and the *application* of science. It often happens, he observed, that theory follows in the wake of discovery, and that experience grows familiar with important details of practice, before the abstract principle involved, is sought out and clearly recognised. In what he advanced in the present lecture, however, a different sequence will be apparent, and we shall have an illustration of the value of a scientific application of common every day facts, in the solution of problems of the utmost moment to human life. He alluded to the property which liquids possess, of assuming the form of a globe or spheroid, when thrown upon any substance which is at a high temperature. Of this property, a familiar instance is afforded by an experiment performed every day in our laundries. When it is required to know whether a smoothing iron is sufficiently hot for her purpose, the laundress on taking it from the stove, applies extemporaneously a drop of moisture from her mouth, and if this at once rolls off in the form of a globule, she knows by experience that the iron has reached a proper temperature ; while if the drop of water bubbles and boils, however violently, the iron is condemned as not hot enough, and returned to the stove.

Once, then, in the flight of ages past it was discovered that water, though it so readily boils when thrown upon a moderately heated iron, does not boil at all when in contact with metal considerably more heated.

This fact, like many others equally familiar, has been allowed to lie unexplained and uninterrogated, during a long lapse of time ; and it is only within the last few years that it has attracted any attention from the physical philosopher.

During his stay in Paris, he had an opportunity of seeing in the laboratory of Dumas, some experiments performed by M. Boutigny of Evreux, who has devoted a great deal of time to the subject, and succeeded in bringing to light some most curious facts ; so contrary indeed, are some of his results, to our preconceived ideas, that he confessed he should hardly have believed them possible, if he had not witnessed them. Some of these experiments he described, showing one or two of the most remarkable by way of illustration, and noticing the important consequences of this property of water, in being the frequent cause of steam-boiler explosions.

It is generally stated in books, that a red or white heat is necessary in order to throw the water into this globular form. Far lower temperatures, however, are sufficient. This may be proved by throwing some water into a saucer of melted lead, a metal which melts long before it becomes luminous in the dark : the water shows no appearance of boiling, but rolls about like a little crystal ball for a considerable time.

M. Boutigny, indeed, succeeded in forming a spheroid of water in a capsule floating on oil, heated to not more than 340°, which is about 600° below what is usually called "red heat."

Liquids, more volatile than water, become spheroidal at still lower temperatures. Alcohol, for instance, requires to be heated to 273°, ether not higher than about 140° ; and it is found in general that those liquids which require the highest temperature for boiling, require also the highest to make them assume the spheroidal form.

Water and other liquids, when in the spheroidal state, slowly and gradually disappear, though no appearance of boiling is even observed. This is of course owing to slow evaporation, which goes on from every part of its surface, thus enveloping it with a film of vapour.

Of the extreme slowness of the evaporation, some opinion may be formed from the fact, which has been proved by direct experiment, that a quantity of water, which would, under ordinary circumstances, boil away at a temperature of 212° in *one minute*, will, if thrown into a vessel heated nearly to redness, require *little less than an hour* for its total dispersion.

The lecturer here illustrated this property by dropping, from a glass tube, three or four drops of water into a red hot capsule of platinum, which he kept hot, and at the same time boiled about the same quantity in another capsule. The drops of water in the latter evaporated very rapidly, while those in the former became one spheroid, diminishing slowly in size, and rotating for a considerable time after the boiling water had entirely evaporated.

We thus see, he continued, that when water is thrown upon a surface of red-hot platinum, it does not, as we might have expected, explode violently into steam ; but, on the contrary, rolls calmly on its axis like a little world in space, and continues in the liquid state for a considerable space of time. Let us then endeavour to ascertain what is the temperature of the globule of water, and what relation it bears to that of the heated vessel, as well as to that of its own thin coating of vapour.

Having again formed a spheroid in the same manner as before mentioned, he plunged into it the bulb of a delicate thermometer, taking care that it did not come in contact with the heated metal. The temperature thus indicated was invariably 205°.

Perhaps one of the most curious facts which have been established in connection with this subject is, that any variation in the temperature of a vessel containing a spheroid, does not affect the temperature of the spheroid itself. Thus, it is found that a spheroid of water, when contained in a crucible heated considerably below redness, is just *as hot* as one contained in a crucible intensely heated to whiteness in the most powerful blast furnace !

From numerous experiments, indeed, with water, alcohol, ether, and many other liquids, the following law may be deduced :—

That bodies in the spheroidal state remain constant at a temperature below that of boiling, however high the temperature of the containing vessel may be.

Pure alcohol, which, under ordinary circumstances, boils at a temperature of 173°, never rises, when in the spheroidal state, higher than about 170° ; and ether, whose usual boiling point is about 100°, and which almost boils with the heat of the hand, *cannot be induced, when thrown into a crucible, heated to whiteness in a smith's forge, to rise above* 95° ! The same remarkable results are obtained, if, instead of pouring the liquids, while cold, into the red-hot vessels, they be absolutely *boiling* at the moment ; strange and almost incredible as it may appear, the instant they reach their fiery resting place, they absolutely become cooler, and, as it were, shaking off the trammels of all known laws of nature, *cease to boil.* Liquids, then, when in that peculiar physical condition, which I have called *spheroidal,* always remain at one definite temperature ; and this temperature is invariably, in the case of every liquid, lower than that at which, under ordinary circumstances, that liquid boils. Let us inquire a little more narrowly into the consequences of this law. Dr Faraday, by a simple and ingenious contrivance, succeeded, some years ago, in condensing into the liquid state, several of the gases which had, up to that time, resisted all such attempts, and had consequently been considered permanent gases, such as the air we breathe. This was the case with carbonic acid, chlorine, ammonia, sulphurous acid, and a few others. So great is the elastic force of these liquified gases, or, in other words, so prone are they to boil, and to pass again into the gaseous form, that a very great pressure is necessary to prevent their doing so, and unless the tube or other vessel containing them were very strong, it would probably be burst with a violent explosion. Now, it will readily be understood how it happens that these condensed liquids, unlike water and other fluids, do not require the application of artificial heat to make them boil, but, on the contrary, continue to boil, even when cooled far below the usual temperature of the air. Let us then inquire whether any of these liquids, whose boiling points are far below that at which water freezes, be subject to the same laws to which water is subject when they are thrown into a vessel sufficiently hot to cause them to pass into the spheroidal state.

The gas which is the most easily liquified of those alluded to, is sulphurous acid, which requires at a temperature of 45° a pressure equal to two atmospheres (or about 30 lbs. to the square inch of surface) to prevent its boiling. If this pressure be removed, violent ebullition takes place ; and it has been found that, even when cooled as low as 14° of Fahrenheit's thermometer, or, in other words, 18° below the melting point of ice, it boils in precisely the same way as water boils when heated to 212°. Fourteen degrees, then, is the *boiling point* of sulphurous acid.

But we have found that when liquids, even while boiling, are thrown into a heated crucible, they *become cooler,* and remain constantly at a temperature a few degrees below their boiling point. What, then, will be the effect of pouring into a red-hot crucible a few drops of liquid sulphurous acid? The experiment which was selected for the purpose of furnishing an answer to this question,

is perhaps one of the most striking and apparently paradoxical in the whole range of physical science. Liquid sulphurous acid is subject to the same remarkable law as water and other liquids, in being invariably, when in the spheroidal state, at a temperature lower than its boiling point, which is 14° of Fahrenheit, so that if a spheroid of sulphurous acid be formed, it remains constant at a temperature of about 12°, even though the crucible containing it be at a red or white heat. If a little water, contained in a small bulb, $\frac{1}{8}$th or $\frac{1}{10}$th of an inch in diameter, be immersed in the spheroid of acid, it is almost instantly frozen, thus affording incontestable evidence of the remarkably low temperature of the spheroid. Most persons have seen the well-known lecture-table experiment of causing water and other liquids to boil in vacuo at temperatures considerably below their ordinary boiling points, a result depending upon the diminished pressure on their surface.

When liquids in the spheroidal state, however, are placed under the receiver of the air-pump, and the air removed, no sign of boiling is even perceived. We may therefore suppose that the temperature of the spheroid in vacuo, is lower than when exposed to the atmospheric pressure, as otherwise ebullition would inevitably take place. The lecturer was not aware, however, that the temperature had ever been examined with a thermometer under these circumstances, and thought it would be by no means easily done.

He should, probably, scarcely be believed, when he stated that even liquid sulphurous acid does not, when contained in a red-hot crucible, and in the spheroidal state, boil in vacuo.

If a thermometer is held in the atmosphere of vapour, which surrounds a spheroid of water, it will give a far different result from that ensuing from its immersion in the globe itself.

Instead of indicating as before, 205°, however hot the crucible may be, the degree at which it stands will now be found to depend entirely on the temperature of the latter. If it be heated to 400° the thermometer will rise to that point; or if the crucible be raised to a red heat, a mercurial thermometer, graduated to 600°, is burst instantly, showing a temperature considerably higher. We have showed experimentally, that when water is thrown into a red-hot crucible, it does not, as common sense would have foretold, begin to boil, but remains constant at the temperature of 205°, so long as it retains the spheroidal form, however high the temperature of the crucible may be, but that the vapour surrounding it is, on the contrary, always about the same temperature as the crucible.

This comparatively low temperature of liquids in the spheroidal state, is generally attributed to the coating of vapour round the spheroid being incapable, as it is conceived, like all other gaseous bodies, of *conducting heat.* This explanation, however, though ingenious, does not meet all the difficulties of the case: for, besides the heat which would be conducted by the coating of vapour, if the vapour had the power of conducting it, (which is possible), there is the enormous quantity of *radiant heat,* emanating from all parts of the heated crucible. If a vessel containing water be placed near a fire, it is well known that it gradually becomes warm, and if the fire be a good one, and the distance not too great, the water will shortly boil. The heat which causes the water to boil in this case, is not conducted by the fire to the water through the intervention of the air, since we know that air has no such power; but it is a portion of that which, like light from a candle, radiates from the fire in all directions, and is absorbed more or less completely by any substance which stands in its way, and intercepts its passage. Why, then, does not the spheroid of water, surrounded as it almost always is, by intensely heated metal, absorb the rays of heat, which dart towards it from every side, become intensely heated to the boiling point, and dispersed in vapour with explosive violence? In order to answer this question, some philosophers have stated that the radiant heat, when it meets with any liquid in the spheroidal state, passes through it without experiencing any interruption, and consequently does not impart any heat to it. A simple experiment is sufficient to show the fallacy of this hypothesis.

If a crucible be made red hot, and a small bulb of glass containing water, be brought near to its inner surface, the water boils violently, owing to the absorption of radiant heat, and notwithstanding the presence of a quantity of non-conducting air between the heated metal and the water. This shows that heat *does* radiate from the sides of the crucible, and, too, in sufficient quantity to cause water to boil with considerable violence. If now the crucible be again heated to an equal degree, and a few drops of water poured in, they at once assume the spheroidal state. Things being in this condition, let the little glass bulb containing water be immersed in the spheroid, and it is found that the water does not show the slightest tendency to boil. The spheroid of water has consequently, in some way or other, prevented the rays of heat from reaching the glass bulb and the water which it contained.

But if, according to this hypothesis, the radiant heat passed through the substance of the spheroid, without being to any extent absorbed or arrested by it, it would obviously reach the bulb containing the water, and cause it to boil with as much violence almost as it does when no spheroid is interposed between it and the source of heat. Another mode of explaining the low temperature of liquids in the spheroidal state, is clearly pointed out by the result of this experiment, which proves, beyond all doubt, *that bodies in the spheroidal state have, when they have attained their maximum temperature (which we have found to be always lower than their boiling point), the remarkable property of reflecting, almost completely, radiant heat.*

A curious variation of the last experiment, tending to the same conclusion, may be made by putting a piece of ice into the red-hot crucible. It instantly absorbs sufficient heat to cause a portion of it to become spheroidal, after which it continues at a temperature of 205°, even though a portion of the ice remain unmelted within the globule. Thus the ice, and afterwards the water, which has an almost perfect *reflecting power* at 205°, absorbs, instantaneously as it were, all the heat necessary to raise it to that temperature, and above which it does not become heated! *Why* and *how* is this? are questions which, in the present state of our knowledge, cannot be answered; and we have here one of those deep mysteries, so frequently met with in our researches into the hidden laws of nature, which baffle and confound the reason, and set at nought, for a time at least, the power of the human mind.

We have seen that not only water, but also alcohol, ether, and liquid sulphurous acid, may be obtained in the peculiar condition, which he had, on account of the external form which always attends it, called the *spheroidal state.* It becomes interesting to inquire, whether so remarkable a change may be produced in other liquids. A great number of experiments have been made with almost every kind of liquid; solutions of acids, alkalies, and salts; compressed gases and melted solids; fats and oils of every kind, both volatile and fixed; and they tend to show that all liquids, with scarcely an exception, pass, under favourable circumstances, into the spheroidal state. The temperature necessary to produce this effect, appears to bear some relation to the boiling point; those which boil most readily requiring a lower temperature than the less volatile substances. That a drop of water, or other fluid, when in the spheroidal state, is poised, as it were, without support, at some sensible distance from the surface of the vessel containing it, may be proved in many ways. If a spheroid of some opaque substance be formed on a nearly flat surface, and then interposed between a lighted candle and the eye, the image of the flame is distinctly seen between the hot surface and the globule. This effect might be produced if the spheroid were in a state of rapid motion up and down, since the image of the candle, seen during the ascent, would remain visible till the next ascent; just as an ignited point in rapid revolution appears as a circle of light. That this is not the case, however, may be shown in another way. If silver be touched with nitric acid, it is rapidly corroded, and in a short time dissolved; but if a quantity of nitric acid be poured into a crucible or dish of silver, sufficiently hot to induce the spheroidal state, no corrosion whatever will take place—clearly proving that the acid is at no time in absolute *contact* with the metal. That this is not owing to any deficiency in the strength of the acid, may be seen by placing in the spheroid a piece of *cold* silver, when violent action of course takes place, nitrous fumes being given off, and nitrate of silver formed. A remarkable effect may be produced, owing to this repulsion between liquids and heated solids, if a large spheroid of water be formed on a surface nearly flat, and a small bar of white or red hot iron be then thrust into the middle of it. *Contact* being impossible between the bar and the water, the latter forms a ring at some little distance from the heated bar, presenting very much the appearance of Saturn and his ring. Whether any real analogy exists between the two effects, or whether the causes be in any way connected, further researches into the nature of that anomalous appendage of the planet may perhaps decide.

We have now passed in review the most important phenomena presented by water and other liquids, when thrown into vessels raised to a high temperature. We found, in the first place, that water may be made to assume the globular form, when placed in a cup heated only to 340°, which is less than 130° higher than its boiling point; and that the temperature necessary to convert other liquids into spheroids bears some proportion to their several boiling points—that for alcohol being 273°, and that for ether 140°. Secondly, we found that the rapidity with which water in the spheroidal state evaporates, is in proportion to the temperature of the heated vessel containing it, but that the evaporation of water in a

spheroidal state is, at a temperature of 400°, fifty times more slow than that of ordinary boiling water at 212°. On examining into the temperature of liquids in the spheroidal state, we arrived at the remarkable result, that *whatever the temperature of the containing vessel may be, that of the spheroids is invariable, and always below their boiling points.* Thus, a spheroid of alcohol always stands at 170°, or 3° below its boiling point; one of ether is always 5° below, or 95°; and liquid sulphurous acid, which boils at 14°, never reaches even that low temperature when in the spheroidal state, but continues far colder than melting ice, even though the crucible in which it lies *be all the time at the most intense white heat.* Fifthly, we found that the only way of explaining this low temperature of spheroids, is to suppose that they have the property of reflecting, in a very perfect manner, the radiant heat emanating from the sides of the hot crucible, and are in this way protected from the scorching rays which would otherwise cause them to burst violently into steam. In the sixth place, it appeared that, with scarcely any exceptions, *all* liquids may be made to pass into the spheroidal state. And, lastly, there appeared strong evidence to prove that spheroids are never in absolute contact with the vessel containing them.

The lecturer proceeded to draw from his enquiry, something of a practical, and therefore perhaps more interesting character, with reference especially to the subject of steam-boiler explosions; a subject on many accounts of so much importance, that no words of his were needed to enlist attention for a short time to it.

Until within the last few days, he had supposed that no one had attempted, previously to M. Boutigny, to account for the explosion of boilers on the supposition that the water in them passes, under certain circumstances, into the spheroidal state. In this, however, he found that he was partially mistaken, and felt great pleasure in saying, that one of his townsmen, Mr Robert Armstrong, some few years ago, advanced an idea on this subject, a good deal similar to that of M. Boutigny. If heat be applied to water contained in an open boiler, the temperature of the water will of course continue to rise until it reaches 212°, when the elastic force of the steam is sufficiently great to overcome the pressure of the atmosphere, and the water boils. If the heat be still continued, the whole of the water will boil away, leaving the vessel empty; but as long as any liquid remains, the temperature of the vessel never rises above 212°, owing to the absorption of heat by the steam. As soon as the boiler, however, is empty, its temperature of course rapidly rises, and may reach a red, or even white heat, provided the furnace be sufficiently powerful. If water be now gradually thrown into the over-heated boiler, we know from what has already been said, that it will pass at once into the spheroidal state, and will continue at 205°, until, from some cause or other, it is permitted to *come in contact* with the heated surface, when violent ebullition immediately takes place, an enormous quantity of steam is instantaneously produced, and if the vessel be a closed one, as is the case with steam-boilers, an explosion is the almost inevitable result. An experiment exceedingly easy of performance, is sufficient to illustrate this. Let a large spheroid be formed in a vessel of platinum or copper; so long as the heat is applied to the latter the water never shows the least sign of boiling; but if the lamp be extinguished, and the vessel allowed to cool a little, the water suddenly comes in contact with the metal, an enormous quantity of steam is instantly formed. A spheroid composed of between four and five pints of water has been, in this way, experimented with, when the sudden formation of highly elastic steam was very striking. If water be boiled for some time in a copper flask, or small boiler, until the whole of the air is expelled, and the vessel be then tightly corked, and the source of heat removed, it is well known that as the water cools and the vapour condenses, a partial vacuum is formed; and, owing to the external pressure of the atmosphere, the cork is held firmly in its place, and offers considerable resistance to any attempt to withdraw it. Far, different, however, is the effect produced, if, instead of boiling the water in a comparatively *cool* flask, it be thrown into one which is sufficiently hot to cause it to pass into the spheroidal state. So long as the flask continues hot, nothing remarkable occurs; but if the lamp be removed and the temperature of the metal be allowed to fall lower than 350° or 400°, a faint noise is shortly heard, and the moment after, a violent explosion takes place, projecting the cork or stopper from the mouth with considerable force.

Now, all this is easily explained. The water on ceasing to be spheroidal, *wets*, or comes in contact with, the heated boiler, and is converted instantaneously into steam, which, being thus generated in vast quantity, finds an outlet at the point of least resistance. This experiment proves that if water exists in the spheroidal state in a boiler, and the boiler be allowed to cool, owing to the extinction of the fire, an *explosion* is the almost certain consequence. A result precisely similar is produced by adding a quantity of cold water to a boiler containing a portion of liquid in the spheroidal form. But here the question arises, Does water really ever become spheroidal in steam boilers? and if it does, what are the circumstances which lead to so dangerous a crisis? That water contained in boilers does pass into the spheroidal state, there can be no doubt; since we know that sometimes circumstances are such that it could not possibly be otherwise, and moreover, it has actually been seen to be so. What then are the causes which lead to this occurrence? The most obvious cause is a deficiency of water in the boiler; owing either to the negligence of the engine man, or to some defect or derangement of the feed-pipe. When this deficiency occurs, the boiler, if the furnace underneath be in action, shortly becomes highly heated, and it is by no means an uncommon occurrence for it to reach even a red heat. If water, under these circumstances, be thrown in, the first portion becomes, of course, spheroidal, and continues so, until, by the addition of a larger quantity, the boiler be so far cooled, as to be unable to maintain the spheroidal form of the water; no sooner is this the case than the spheroid comes into contact suddenly with the overheated boiler, bursts into steam, and in all probability, an explosion is the result. Another and highly probable cause of water becoming spheroidal is suggested by Mr Armstrong, in his excellent work on Steam-engine Boilers, and which is well worthy of notice. After alluding to the subject of boiler incrustations, and the effect they have in preventing the passage of heat from the furnace to the water, owing to their non-conducting property, he says:—

"Under similar circumstances to those just mentioned, there can be no doubt that a portion of the boiler occasionally becomes nearly red-hot, although this condition appears extremely inconsistent with the supposition, that it is at the same time covered with water; yet we have been compelled to adopt this conclusion, from having had ocular demonstration of its possibility, as well as other reasons. We had frequently heard the fact stated by intelligent engine men, and had been called, more than once, to witness it, although even then inclined to consider it a mistake, owing to the difficulty of ascertaining it clearly; for a slight approach to the incandescent state must be nearly invisible, owing to the strong glare of light from the furnace directly beneath, while any degree of heat much higher, would be sure to weaken the iron so much as to cause the boiler-bottom to give way. The probability of boilers sometimes approaching a red heat, receives a corroborative proof on examination of the iron plates, in cases when the boilers have bulged out, and which exhibit an appearance, well-known to boiler-makers by a peculiar colour in the iron surrounding the part which has been red-hot.

"Whenever," he continues, "a boiler is seen in this state, of course the only method of avoiding danger is to slack the fire immediately by opening the fire doors. But it frequently happens that the fireman thinks that the boiler is empty, and if he has an opportunity, he immediately lets into it a quantity of water, when the *consequence uniformly is, that the boiler bursts instantly.*"

The bursting in this case we can now readily understand. It is precisely similar to our last experiment, in which the spheroidal state of the water was destroyed by the addition of a quantity of cold water.

Mr Armstrong goes on to say,—"From what we have stated above as the common practice in some districts, we may conclude that the principal cause of boilers becoming unduly heated, is undoubtedly, in a majority of cases, owing to the interposition of indurated or encrusted matter between the heated *iron and the water*, and the manner in which those circumstances operate in producing an explosion, appears to be as follows:—

We have before shown that an internal coating of boiler scale is liable to crack and separate into larger pieces, which are thrown off from the boiler, with a certain degree of violence, at some particular degree of temperature, depending upon the thickness of the scale, and the kind of substance of which it is formed." He then proceeds to explain how, by the sudden separation of those pieces of encrusted earthy matter, the water flows upon the overheated metal, when, of course, the result will be, that a portion of the water becomes spheroidal, which, on subsequently coming in contact with the hot surface, is immediately converted into steam. Seeing then, the imminent danger which always attends the presence of the spheroidal water in a boiler, it becomes a question of the highest importance, whether any means can be devised, which will effectually prevent such an occurrence.

If it were possible to ensure a constant, uniform, and never-failing supply of water to the boiler on the one hand, and to prevent

the accumulation of earthy sediment or crust, on the other, there would be little or no fear of the water ever becoming spheroidal. But there are great and serious obstacles in the way of these conditions being practically complied with; both on account of the liability to derangement which affects most kinds of feeding apparatus, and the great difficulty which exists, both in preventing and removing the depositions of the earthy matters which are found more or less abundantly in most kinds of natural water.*

It has been found that the more smooth and even the surface of a metal is, the more prone is water or any other liquid, on being thrown upon it, to pass into the spheroidal state; and that any great roughness, or especially the presence of sharp points considerably lessens the danger of such a change. There is, however, a great objection to fixing projecting points in a steam-engine boiler, on account of the difficulty they would occasion in cleaning it out; and the idea occurred to M. Boutigny of placing in the boiler, loose pointed pieces of iron, of such a shape, that one of the points should always be uppermost.

Before concluding, he would say one word respecting the possibility of preventing an explosion, even when the water *has* become spheroidal in a steam-boiler.

And here an experiment, which we have already seen, will suggest the best mode of proceeding, in order to avert the impending danger. When water was thrown into a hot platinum crucible, and thus made to assume the spheroidal form, we found that so long as the crucible continued hot, the globule floated on its bed of vapour, slowly and gradually evaporating, and showing no appearance even of boiling, still less of passing explosively into steam; but no sooner did we allow the crucible to cool down to a certain temperature, than the water, on touching its still over-heated sides, was instantly dissipated in the form of highly elastic steam.

If then, it be ascertained by the engine man, that the water in a boiler has become spheroidal, his chief care should be to keep up the fire, and also to prevent most completely the influx and further supply of water; since non-compliance with either of these conditions, would cause the cooling of the boiler when the spheroid would, in all probability, shortly be converted suddenly into steam, and an explosion would be the almost inevitable consequence. But if, on the other hand, that spheroid be *not* allowed to touch the boiler, it will calmly and slowly evaporate, without occasioning any further inconvenience than rendering the engine comparatively inactive, until it has returned to the natural condition.

The advice then, relative to this subject, which should be given to those who have the charge of engines is simply this:—

1*st.* Be careful that the boiler is kept as free as possible from earthy incrustations, which if allowed to accumulate, form, in fact, a boiler of stone inside the iron one, and thus retard the passage of heat from the fire to the water, until the iron has become more or less overheated.

2*ndly.* Never let there be a deficiency of water in the boiler, since, when that happens, the latter may become heated almost indefinitely, and is consequently sure to render the water spheroidal, when thrown in; when an explosion will be (without great care) almost certain.

And lastly, If it be known that, owing to any cause, the water in a boiler has already become spheroidal, instantly stop the supply of water, and take care that the fire is well kept up, until the whole of the water is evaporated; when that is the case, the boiler should be allowed to cool to its natural temperature, when water may be added, and the fire rekindled.

* As most kinds of spring and river water contain, in solution, some earthy matters, which are left by the evaporation of the water, giving rise to the formation of sediments and incrustations, it had often occurred to the lecturer that rain-water might be substituted with great advantage.

GLEANINGS FROM HUMBOLDT'S KOSMOS.

A GENERAL SURVEY OF THE PHYSICAL PHENOMENA OF OUR PLANET.

The book, the title of which stands at the head of this article, is the production of one of the most remarkable men who have devoted themselves to the study of the material universe in this or any former age. As a traveller amongst the wilds of the new world, as a successful investigator of many dark departments of natural science, as an assiduous collector of facts, he has been known to the world for fully half a century. The accomplishments, the qualities of mind and body, the acquirements with which he went armed into the field of science were so numerous, and so well adapted to his purpose, that we are lost in astonishment when we see them all carried by one person. If we look at the variety of knowledge which he has studied, we might conclude that he must have lived in times when a single volume would have contained a perfect circle of the sciences, observation and theory, at length and unabridged. If we look into the depths where he has penetrated, in some single divisions, we might suppose that any one division had occupied his whole lifetime's attention. His extraordinary mind seems equally suited to gather and analyse the grains which make up the mass of truth; and to climb those heights whence grand views of all nature may be taken in. We see him at one time tracing the connection and derivation of an articulate sound; at another, pursuing the intricacies of an abstruse mathematical calculation. Our obligations go still further; not only has he by his individual efforts dissipated the clouds that rested on many phenomena, but he has strenuously exerted himself to form a society in which every civilised nation should be represented by philosophers. For those exertions honour to his name! The object of this article however was not to set forth the biography of Alexander von Humboldt, but to give an account of Kosmos. Its aim, so far as the three volumes which have been yet translated into English disclose, has been to set before us an outline, with scientific explanations, of "this great temple which we look up to, the pavilion of the sky, the moon, the atmosphere, with its climates, and its winds; and this home which we inhabit, the earth with its hills and rivers." For a work of this kind the studies of his life have been preparatives, and in the evening of his days he has sat down to write it. He was early convinced that without an earnest devotion to the science of individual things, general views of nature would be nothing more than airy dreams.

He commences his survey of nature with the objects that lie most remotely buried in the depths of space, nebulæ, and fixed stars; then he passes to our own system, and finally he considers our own globe. For the present we shall forbear to enter upon the phenomena of astronomy, though he holds the pencil with the hand of a master; we shall probably have an opportunity of recurring to this part of the subject, with reference to other recent publications.

It is with a sensible relief that we descend from the region of celestial formations, where time and space are inconceivably vast, where no vital movement is revealed to us, and no sound is heard, to the narrower domain of terrestrial forces. We cannot however make that descent without perceiving that there is a band that mysteriously binds together both classes of phenomena, and though much is still unknown, and the connection is not so vividly seen as it will be, yet even now it is impossible to understand the operations of the earth unless the whole mighty order of nature is subjected to our contemplation. If it were possible for us to retire so far from the ball we inhabit as to see at once the whole sphere, and yet have powers of eye-sight sufficient to discern the exterior parts with distinctness, the first thing that would attract our attention would be the envelope of transparent gaseous particles floating above its solider portion, and next the distribution of that solider portion into land and water. The elastic fluid we denominate the atmosphere, is the grand supporter of life; without it nothing that now lives, could any longer exist. It is the carrier of sound, and in its absence all intercourse of man with man would be conducted by signs. It is principally composed of two gases, oxygen and nitrogen, nearly in the proportion of 29 and 79, and a slight admixture of other gases. Oxygen is one of the indecomposible substances, and it is this alone that feeds the breathing apparatus of animals. The limit of the atmosphere is not accurately known, but it is supposed to be somewhere about 50 miles above the earth's surface. As we ascend, both temperature and density decrease, the former in the proportion of a degree

of Fahrenheit to 106 yards. We must consider the atmosphere as an aerial ocean sustained partly by the firm earth, whose mountain summits and high table lands lift themselves into it like green and wooded shoals, and partly by unstable water upon which lie the denser and moister strata. Being an accumulation of mobile particles, it is subject to fluctuations, some of which are regular and calculable. The disturbing causes are the action of the sun and moon, of heat and electricity; and where the atmosphere rests upon the ocean, of course the unsteadiness of its base acts upon the superincumbent mass. It would be foreign to our purpose to enter upon the sciences of Climatology and Meteorology, subjects of great complication, requiring an immense number of observations to the establishment of any one fact, and as yet quite in their infancy. The atmosphere even in its driest state always holds some quantity of water, but the amount varies not only with the degree of latitude and the hour of the day, but with the season of the year, and the height above the level of the sea, because the temperature exercises so great an influence over the power of the atmosphere in this respect, and that is always fluctuating. When the water is visible, it takes the form of cloud mist, and when precipitated on a sudden change in temperature, or other causes, we have rain or snow. That there is water floating about in an invisible state is shown by the trees in tropical countries where, for many months together there is no rain or dew and not even a cloud to stain the face of heaven. Yet their fresh verdure proves that the leaves must have the power of absorbing water from the air. Late investigations have shown the incessant activity of electricity in all matter, nay, exerting a most powerful influence on the whole of the animal and vegetable world.

The area of dry land to that of water on the surface of our globe is about 100 to 270, and of *terra firma*, nearly one twenty-third consists of islands. The prevailing character of the southern hemisphere is much more oceanic than in the northern where the superficial extent of land is three times greater. It is not known whether the Poles are surrounded with dry land, or with an ice ocean; for the North Pole has been approached only within seven degrees nearly, and the South Pole within eleven degrees. A glance at the map will show how the land crowds towards the Northern Pole by preference, and how all the great continental masses terminate pyramidically on the south, a configuration repeated on a smaller scale in the great Indian ocean, and in the Mediterranean. The Atlantic ocean seems to have been an immense valley, scooped out by floods that directed their force first to the north-east, then to the north-west, and then to the north-east once more. This view is supported by the parallelism of the opposite coasts of the hemispheres where we see indentations standing over against projections. The present shape of the land is the product of two causes that were exerted successively; firstly, subterranean force, the measure and direction of which we have no means of discovering, secondly, powers that are at work on the surface. The elevation of continents has been an actual not an apparent one only, and is going on over vast areas at this moment. The coasts of Sweden and Finland are rising, it is said, at the rate of four feet in a century. On the south the upheaving power abates until as some observers affirm, the land sinks. Lines of old sea levels are indicated along the coasts of Norway, by shells deposited by the present ocean, which lie six hundred feet above the present sea level. There are some spots on the face of the globe, in the interiors of continents, which actually lie lower than the present uniform level of the ocean; nor is this surprising when we consider the oscillations of the soil in the earlier ages of our planet.

The Dead Sea is no less than 1230 feet lower than the Mediterranean, and the sea of Tiberias 125 feet. The enormous powers that have been at work at some former period acting from within, are shown by the vastness of the mountains that traverse the earth in many parts in long chains, and yet, the quantity of the upheaved masses is insignificant when compared with the areas of the continents from which they rise. It has been calculated that if the matter composing the Pyrenees were distributed evenly over France, the surface of that country would be raised by no more than 108 feet, and if the eastern and western Alps were in like manner scattered over Europe, the result would be to raise the continent only twenty feet. By a laborious process, Humboldt calculated that the centre of gravity of the whole mass of earth which in Europe and North America, rises above the level of the sea, is between 630 feet and 702 feet in height; in Asia and South America a similar calculation gives a result of between 1062 and 1080 feet. If the whole waters of the ocean were to be drawn in from the hollows which they now cover, we should see then the irregularities in the surface of the earth doubled in extent, and the heights to which the mountains rise, would be visibly contrasted with the depths filled with liquid. Man would then perceive with some surprise that the tolerably level countries in which he has pitched his dwelling are in fact shelves half-way up elevations, the highest of which attain to between fifty and sixty thousand feet. In some parts of the ocean, no bottom has been touched with a line of 25,300 feet, 4⅘ English miles. The temperature of the sea varies like that of the air in various climes; but a series of careful observations teach us that in the usual state of the sea's surface from the equator to 48° of N. and S. latitude, it is a little warmer than the stratum of air that is upon it. It has also been discovered that there are great currents running underneath from either Pole to the equator. The attraction of the sun and moon cause those regular and periodical disturbances of equilibrium which we term tides. In the open ocean the rise is not more than a few feet, but the opposition of coasts causes an elevation of water in some places to between 60 and 70 feet. In addition to under-sea currents there are currents along the surface which exercise a considerable influence on the intercourse of waters, some of them narrow enough to deserve the term of oceanic rivers, since they run through the main mass of water like streams between unmoved banks of land. There is the well-known gulf stream, which commences south of the Cape of Good Hope, runs through the Caribbean Sea, the Gulf of Mexico, and the Straits of Bahama, turning eastward by the banks of Newfoundland, crossing the Atlantic, and frequently throwing the seeds of tropical plants on the Irish coast. The Pacific ocean has its great current also, that brings the cold water of high southern latitudes to the coast of Chili, and runs northward for some distance before it turns to the west. Ships in traversing that ocean will suddenly find a difference of 20° in the water when they pass from the adjacent water into this current.

Having thus considered apart the two great constituents of our ball, let us now consider them as forming one globe. Mathematical calculation and actual admeasurement both give us this testimony that it is not a perfect sphere, but flattened at the Poles, so as to constitute the figure called an oblate spheroid. The history of the sciences, says Humboldt, presents us with no problem second in importance to that which seeks to discover the figure of the earth. The results of the different plans employed, differ to some extent, but the circumference measured round the poles is usually stated as one-299th less than that measured round the equator, in other words the earth bulges at the equator to something like 4½ times the height of Mont Blanc. If this globe were a mass of water, the figure impressed upon it by rotation round an axis would be a regular oblate spheroid, but though the original fluidity of our planet is shown by its oblate figure, (oblateness resulting from the operation of a centrifugal force on a rotating mass), yet the true shape stands in the same relation to a regular figure as the uneven surface of ruffled stands to the even surface of unruffled water.

Our earth has not only been measured, it has been weighed also. The latest researches give its mean density 5·44, that is, the earth is very nearly $5\frac{1}{2}$ times denser than pure water. Now, as the mean density of the mineral matter constituting the crust is only 2·7; and the mean density of that crust and the ocean, is no more than 1·6, we see at once how vastly the density of the interior must be increased by pressure or some other cause. We have penetrated no further than 2000 feet below the sea's level, or one 9800th of the distance between the surface and the centre. No doubt our knowledge of the contents of the earth extends to a much greater depth, for some of the crystalline matters thrown up by volcanoes come from a depth many times greater than that to which man has reached; and by the contortions of strata we are made acquainted with substances which, if no throes had disturbed their repose, would have been lying at least 12,000 feet beneath our feet. There is a regularly progressive increase of temperature with an increase of depth, and the discharge of molten minerals through gaps in the surface, declare plainly that there is an enormous heat kept alive below. The warmth of the sun is communicated at a slow rate, and to a short depth only to the earth, and there are points where the temperature is always the same. Between the parallels of 48° and 52°, on the continent of Europe the stratum of invariable temperature occurs at from 55 to 60 feet deep, whilst in tropical climates it is found at no more than a foot below the surface.

Those awful occurrences, called earthquakes, by which the ground is shaken and convulsed by subterranean force, are not very frequently experienced in Europe, but in hotter climes and particularly in South America, they have done great damage to life and property. In 1797 the town of Riobamba was destroyed, between 30,000 and 40,000 persons were killed, and the bodies of many inhabitants were afterwards found thrown upon a hill several hundred feet high. Walls were twisted round without being thrown down, and rows of trees were deflected. In the great earthquake of Lima and Callao, 1746, there was a sound like subterranean thunder heard after it had occurred, but the ground was not again shaken. Sometimes underground noises are heard without any trembling of the earth as in 1812, a region of 2300 square miles in South America, was alarmed with thundering noises, and in January 1784 subterraneous bellowings were heard in some of the high lands of Mexico for more than a month. No earthquake ever committed such ravages in Europe as that of November, 1755, when Lisbon was laid on the ground, and the plains of Germany, as well as the lakes of Canada felt, its influence. Perhaps if we had a knowledge of the things going on in the interior of the earth, we might perceive that there is uninterrupted action against the crust going on; another spasmodic affection of the ground are the volcanoes which at a few points along the surface, throw out occasionally quantities of earthy and metallic substances, which when melted, formed lava. The navigator may change the stars and the vegetable life to which he has been accustomed, but he meets with volcanoes under every clime. Amongst the islands of distant seas, surrounded by palms and strange plants, he can still trace repetitions of Vesuvius, the dome-shaped summit of Auvergne, the craters of the Canaries and the Azores, and the fissures of Iceland. The peak of Cotopaxi, amongst the Andes, is one of the highest volcanic peaks in the world; it is 7892 feet in height, and the Peak of Teneriffe is 11,424 feet high, the middle point of a group. There are emanations of different kinds in many parts of the world, which also show a forcible action going on below. Of carburetted hydrogen, carbonic acid and other gases, sulphur fumes, hot water, &c. there are several escapes in various places.

If we look at the mineral masses of our globe with reference to their mode of production, we discover a four-fold process, namely, eruption, which throws out rocks from the interior in a liquified or softened state; sedimentation, which deposits particles previously suspended in fluids; metamorphosic heat, which alters rocks in their structure and stratification, either by contact with molten matter, or by the penetration of sublimed vapours and conglomeration, by which mechanically divided rocks are united by other materials. These processes are going on at the present day. Of rocks brought to our knowledge by eruption, granite, porphyry and basalt, are instances. Limestone and slate are examples of the second process. Had the igneous rocks not exerted themselves upon the sedimentary strata, the surface of the globe would have consisted of uniform strata horizontally disposed, a dreary monotony like the plains of North America, or the steppes of northern Asia. The influence of the heated matter from underneath, was not simply of a dynamical kind, by shattering and upheaving the strata lying above, but a chemical change was occasioned in their constituents and in the nature of their coherence. Through the rents violently made, vast masses of melted mineral have been forced up to fill the fissures, and sometimes they have issued to the surface through a narrow opening, and then spread out above, like the cap of a mushroom. The rock in contact with the heated mineral has undergone the change called metamorphic; and thus clay-slate becomes granular and a granite-looking mass, and the earthy structure of limestone also is converted into a granular one. The marbles called parian and carrara, in which most of the efforts of sculpture have been enshrined, have been acted upon in this way. The conglomerate rocks have been principally produced by the action of water, which has broken up into fragments the strata whereupon its immense force has been directed, ground them against one another, and then subsided, leaving the process of their second combination to be performed by cements of various kinds. Most of the sedimentary strata contain fossilised animal remains; the igneous rocks by their very nature cannot. The application of botanical and zoological knowledge to the determination of the age of strata, marks one step of the great advances which of late years have been made in geology. The fossiliferous rocks present us with the different objects of bygone periods preserved as it were for our consideration, and it is astonishing what minute and delicate objects have been transmitted to us through myriads of years. The traces of footsteps on wet sand; indigested food, even the ink bag of the sepia has been found so perfect that the same material which the animal employed centuries, nay, thousands of years ago, to preserve itself from its enemies, has served for colour to paint its likeness with! Enormous quantities of vegetable matter sometimes entirely petrified, sometimes merely carbonised, have been discovered in many quarters, and they give us a vivid idea of the luxuriance of vegetation that characterised the ancient world.

SHORT READINGS IN ELECTRICITY.

By Mr. R. Smith, Blackford.

II.

The phenomena of attraction and repulsion which accompany the transfer of electricity by moveable conductors, is beautifully illustrated by placing a metal plate upon the table, below the prime conductor. Having then cut a figure out of a piece of paper, such as a representation of a harlequin, place it upon the plate, and suspend another plate, by means of a wire, from the prime conductor, above the plate upon the table, so as to be parallel with it, and about an inch and a half separate from it. When the machine is set in motion, the paper figure will be attracted by the upper plate and will move up and down between the two plates, transferring the electricity from the upper one to the lower, and producing the most fantastic movements, as in the act of dancing. The transfer of electricity may also be exhibited by the motions of a ball suspended by a silk thread and placed between two small bells, one of which is electrified, and the other connected with the

earth; the alternate motion of the ball between the bells keeps up a continual ringing. This experiment has been applied to give indications of the electrical changes of the atmosphere.

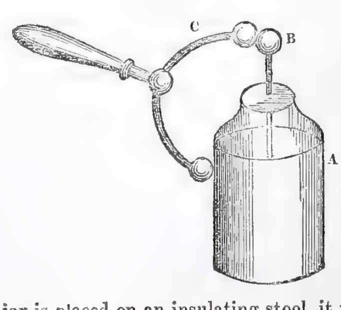
Another interesting experiment, illustrative of attraction and repulsion, may be easily exhibited, by fixing the end of a chain to the prime conductor, and making the other end to lie in various folds in the bottom of a glass tumbler; after a few revolutions of the machine, the outside of the tumbler becomes positively electrified, and when in that state, if quickly removed and placed over three or four pith balls, the balls will be quickly put in motion, ascending and descending between the table and the inside of the tumbler, and will continue their salient movements till the charge of electricity contained in the glass has passed to the table. Various sounds accompany the different modes of transferring electricity, and sometimes a peculiar odour has been felt when a machine was in very rapid motion, but the origin of it is as yet unknown.

Currents of air also accompany the discharge of the electric fluid from all sharp pointed bodies, and this property has been made the basis of a variety of ingenious experiments. An apparatus may be constructed that imitates the motions of the heavenly bodies, called the electrical orrery—it consists of wires terminating in points poised upon a centre, and having balls annexed to them, to represent the planets, the whole being constructed so as to revolve when electrified. The electrical chace, is a variation of the last experiment, and is exceedingly amusing. On the top of a pointed wire inserted in the hole on the upper side of the prime conductor, is another wire, made to move freely upon the centre; it is sharpened at the ends, and the points bent horizontally in opposite directions; when electrified, it will move very swiftly round, by the re-action of the air against the current which flows from the points, and by increasing the number of wires proceeding from the centre, figures of men and horse, with hounds and a stag or fox, may be placed upon them, when they will appear as if in pursuit. The celebrated James Ferguson, the astronomer, applied the electric current for setting the model of a corn-mill in motion. This little machine is constructed of card; when the model is to be set in motion, it is placed near the prime conductor, and a crooked wire, having a sharp point, is inserted in the conductor. The points being directed to the upper side of the wheel, on putting the electrifying machine in motion, the electric current issuing from them will turn the wheel, and consequently all the other motions of the model. The mutual repulsion of similarly electrified bodies, is curiously exhibited in the following experiments:—A figure in the form of a human head covered with hair, being placed upon the prime conductor, and electrified, will, by the divergence and bristling of the hair, represent the appearance of terror. In the same manner, a small lock of cotton suspended from the prime conductor, with a linen thread, when electrified will immediately swell by repelling its filaments from one another; in this situation, if the finger be brought near it, the cotton will move towards the finger and endeavour to touch it—if a pointed wire is presented with its point towards the cotton, a little above the end of the finger, the cotton will shrink from the finger—remove the wire, and the cotton will again approach it. The appearance of the electric spark depends entirely upon the nature of the surface of the body from whence it escapes, and also towards which it is directed. When it issues from a sharp point, the luminous appearance is that of diverging streams resembling the bristles of a brush, which is called a pencil of light; but when the electricity enters a point, the light is concentrated, and then it assumes the appearance of a star, the difference of the two luminous appearances will in a great measure serve as a criterion for indicating what kind of electricity is passing from one conductor to another. When a point is presented to an electrified body, if a star appears, it may be considered that the body contains positive electricity, while the luminous pencil will indicate that the body is negatively electrified. When an electrifying machine is in vigorous action, the intensity of the electricity will be augmented, and while in that state, if a pointed wire be attached to the prime conductor, this, in obedience to the laws already explained, will cause a current of wind sufficiently strong to extinguish a lighted candle; this stream of wind has received the name of the electrical aura.

Having already adverted to the principle of induction, we now come to consider the more general operation of this law, and the application of it is, that a greater quantity of electricity can be obtained in a smaller space, and with a less tendency to escape. A plate of glass is covered on both sides with tin foil, leaving a margin round the edge of the glass, to prevent the transfer of the electric fluid from the one coating to the other; the glass thus coated, is mounted on a stand furnished with a pair of pith balls, one side being charged with positive electricity, and the other connected with the ground. The ball on the excited side will immediately diverge, and the other will remain uninfluenced—as the electric charge becomes dissipated, the ball will slowly descend, and if the communication between the unexcited side of the plate and the earth, be cut off, the ball on the excited side will rise to about the half of its elevation, and the ball on the other side will rise to an equal height; if it is touched with the finger, it will quickly fall, while the other rises: remove the finger, and the reverse will ensue, then both will slowly descend. This process may be repeated a considerable number of times before the equilibrium is restored—instead of discharging it gradually, if a communication be made between the two coatings with a metallic wire, a bright flash will be the result, or if instead of the wire, a finger of each hand is placed on the opposite coatings of the glass, a violent impetus will be felt which electricians have termed the electric shock. A curious device is constructed called the electric portrait; it consists of the picture of a king, contained in a frame of baked wood, and a glass. The print is cut out at about an inch and a half or two inches from the frame, according to the size of the print, and the border thus cut off is fixed on the glass with gum or paste, and the vacancy filled up by covering the glass with tin foil; after this, the back of the pannel containing the print that was cut out, is pasted over it, so that the print and margin will again appear as if whole—another piece of tin foil, the same size of the former, is fixed in the same manner, on the opposite side of the glass, and is then put into the frame, and a portion of the middle of the under part of the frame is covered with tin foil, and made to communicate with the foil on the glass, of the same size. The picture is then held by the top of the frame, and a small moveable gilt crown is placed on the king's head; if the picture be electrified, and a person take hold of the bottom of the frame, so that his fingers touch the tin foil, and with the other hand attempt to take off the crown, he will receive a smart shock, while the person that holds the frame by the upper end will feel nothing.

From what has been formerly said on the principles of induction, we have no difficulty in understanding what may be termed the theory of the Leyden phial, or electrical jar. This instrument derives its name from the town of Leyden, in which it was invented, and the circumstances connected with its discovery have been already mentioned. The Leyden phial, is a cylindrical jar coated with tin foil nearly to the top, both on the inside and outside; the cover is made of baked wood, and is inserted into the mouth of the jar with sealing wax. A rod descends through the cover until it touches the interior coating, while the other end projects about three inches above the cover, terminating at the top in a brass ball. When the jar is to be used, the outer coating is made to communicate with the earth, and the brass of the jar is placed near the prime conductor of an electrifying machine in motion, when a succession of sparks will pass from the conductor to the jar, while an equal quantity of electricity will pass from the outer coating to the earth. According to the Franklinean theory, the inside of the jar will become positively, and the outside negatively electrified. When a communication is made between the internal and external coatings by means of the discharging rod being brought into contact with the outer coating and the brass ball, the sudden transfer of the accumulated electricity causes an explosion to take place, producing a vivid flash of light, the intensity of which corresponds to the magnitude of the charge. Fig. 1, is a view of the Leyden phial; A, the tinfoil coating; B, the ball and rod; C, the discharging rod with glass handle.

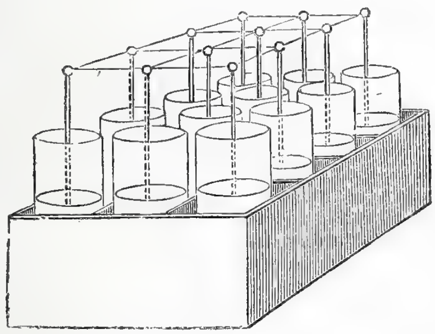
Fig. 1.



When the jar is placed on an insulating stool, it will be found impossible to charge it, but when placed in that position, if the knuckle is presented from time to time to the outer coating, a

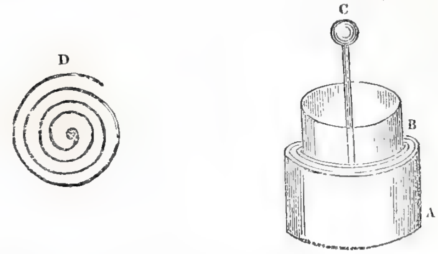
spark will at each time appear, and the jar will become charged. If the nob of another jar is now brought into contact with the coating, it will receive a charge. A number of jars may be thus charged, provided they are insulated, and the last one made to communicate with the earth. If a Leyden jar be suspended from the prime conductor by the nob, with a metallic wire, and the outer coating is connected with the negative conductor, after a few turns of the machine, the jar will be charged with its own natural electricity, as all communication is cut off between the earth and the jar, the electricity of the exterior coating is transferred to the negative conductor, when it passes to the glass cylinder, and from that to the prime conductor, and thence to the interior of the jar. In these experiments the inside of the jar is positively and the outside negatively electrified; by reversing the order of arrangement, the charge is easily reversed also, and we have only to place the jar on an insulating stool and make a communication between the internal coating of the jar and the earth, and the external coating and the machine, when the outside of the jar will be positive, and the inside negative. If two jars of equal size are electrified, one positively, and the other negatively, and placed on an insulated stand, and a connection is made between the two nobs with the discharging rod, no explosion will take place, although apparently from these conditions we might expect this to ensue, being oppositely electrified; but if at the same time the two exterior coatings are in communication, an explosion will be the result, and both jars will be reduced to their natural state. For experiments on the decomposition of substances, such as the burning of metals, &c. &c., to which we will have occasion to advert, a large accumulation of electricity is requisite, and this is effected by uniting together a number of Leyden jars, by placing them in such a manner that their exterior coatings are in communication with one another, while the interior coatings are made to communicate by metallic rods, which connect the nobs of the jars together. When thus arranged, they form what is termed an electrical battery, and the whole series may be charged, as if they were but one jar, and the whole accumulated electricity may be made to pass from one system of coatings to another by one simultaneous discharge. Fig. 2, represents the electrical

Fig. 2.



battery. The author has been successful in devising an electrical jar, which will be found very useful for accumulating a large quantity of electricity in a small compass; its being portable is of considerable importance, while its construction is exceedingly simple. The following is a description of the method of constructing, and employing it: the end of a ribband of tin foil is first attached to the under end of a brass rod, (with a nob similar to that which is used in constructing the common Leyden jar), by winding it once or twice round the rod; a ribband of cotton cloth covered with gum-lac varnish, is then placed on the inside of the tin foil one, and both are wound together round the rod, until it fills the diameter of the jar intended for the purpose. It is then pressed down into the jar until it reaches the bottom; the rod will then stand perpendicularly in the centre of the jar, with the nob on the top of it. A ribband of tin foil, and another of varnished cotton, about the same length as the inside ones, are then placed together and wound in the same manner round the outside of the jar, the underside of which is straight with the bottom of the glass, the cloth ribband of the inside coil being a little broader than the tin foil, in order to completely insulate the metallic band, and the outer ends of the ribbands of the exterior coil are to be kept together by means of paste or a little glue. The breadth of the coils is in proportion to the size of the jar, that is, they must cover as much of the surface of the glass as the coatings of a common Leyden jar. It is difficult to get tin foil long enough to form the ribband in one piece, and in that case, they may be formed of pieces glued together.

Fig. 3.

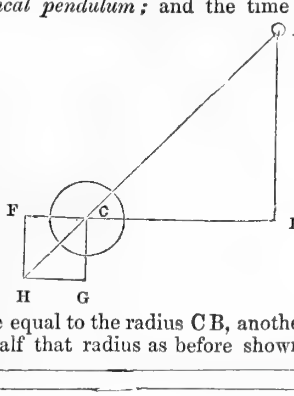


The diagram, fig. 3, is a representation of the coil electrical jar. A, the exterior coil; B, the glass jar; C, the brass rod with nob; and, D, the manner in which the interior coil is wound up. A jar of this kind constructed with a small tumbler, only 3 inches in height, and $1\frac{1}{2}$ inches diameter, containing coils 8 or 9 feet long, and $1\frac{1}{2}$ inches broad, will, when properly charged, melt a small piece of flat steel spring wire and will also produce a shock, more powerful than agreeable to the recipient. Those who are unacquainted with electrical experiments, would be apt to suppose that the accumulated electricity is extended over the tin foil coatings, but this is by no means the case, as the following experiment will show:—Let a jar be provided with moveable coatings made of thin sheet lead or tinned iron, and let a piece of glass tube be placed on the brass rod a little below the nob, which communicates with the interior coating, this glass serving for an insulating handle to remove the coating when required. The jar is charged in the usual way, and the interior coating is removed, by means of the glass tube; the jar being then turned on its mouth upon a glass plate, and the exterior coating removed; and both coatings may be handled in any way whatever, without giving the slightest signs of electricity,—replace the coatings, and then make a connection between them, with the discharging rod, and an explosion will ensue. Fresh coatings may even be applied to the jar instead of the others, with the same success, and an explosion will pass. The accumulation of the electricity is proved by this experiment, to be on the glass, and not on the metallic coatings; the coatings only serve the purpose of conductors to diffuse the electricity over the surface of the glass, and again to collect it to a point at the instant of discharge. In the coil jar the varnished cloth ribbands serve the same purpose as an extended surface of glass, the electricity being spread over them, as it would be over a surface of glass, being non-conductors, as the interior and exterior coils contain the same extent of surface. When the jar is charged, the negative electricity passes to the earth from the outer coil, as the positive accumulates on the inner. Hence the coil jar acts in the same manner as the Leyden phial, formerly explained, only there is a vast increase of surface; consequently there is a great increase of power also.

TERMS USED IN MECHANICS.

IV. CENTRIFUGAL FORCE—ILLUSTRATIONS.

If a ball, suspended obliquely from a point by a thread of a thin rod, describe a circle in the horizontal plane, it will form what is called a *conical pendulum;* and the time of revolution will be equal to the time occupied by a cycloidal pendulum of the same length in making two vibrations, that is, in vibrating once forwards and once backwards to the point at which the motion began. For, supposing the distance C B to be equal to the height A B, the central force will be equal to the force of gravity, and while the ball describes a distance equal to the radius C B, another body would fall through half that radius as before shown,



and the whole time of revolution is therefore to this time as the circumference to the radius, and is consequently equal to the time of four semi-vibrations of a cycloidal pendulum, of which the length is equal to the given height. Otherwise, if the ball C circulate about the axis A B, it is evident (from the composition of forces) that a strain C H in the direction of the pendulum must be compounded of C G, the vertical power of gravity, and C F the horizontal centrifugal force. And this being true, the action of gravity will be to the centrifugal force as C G to C F, and consequently, the triangles being similar, as A B the height to B C the radius of the circle in which the ball revolves. But the time of revolution remaining constant, the centrifugal force will be proportional to the radius of revolution B C, and therefore the perpendicular A B, representing the power of gravity, must continue likewise unvaried; and from this it follows, that if a number of balls be attached at the point A by threads of different and of greater lengths than AB, and be carried round in the same time, they will always arrange themselves in the same horizontal plane parallel to CB.

To express these conditions arithmetically, let us denote the height in feet AB by h, the power of gravity CG by 1; then, since

$$AB : BC :: CG \quad GH$$

$$h : R :: 1 : F \quad \text{therefore } F = \frac{R}{h}$$

But we before found $F = \frac{4\pi^2 R}{g t^2} = \frac{\pi^2 R}{8 t^2}$ if g be taken $= 32$ which involves an inappreciable error. Therefore by equating these two values of F we have

$$\frac{R}{h} = \frac{\pi}{8} \quad \frac{R}{t^2} \quad \text{whence } t^2 = \frac{\pi^2}{8} \cdot h$$

an expression from which we learn that, $\frac{\pi^2}{8}$ being constant the height of the axis of the conical pendulum is proportional to the square of the time of revolution.

Putting for $\frac{\pi^2}{8}$ its arithmetical value 1·2337, we have

$$t^2 = 1{\cdot}2337\, h \text{ or } t = 1{\cdot}11072 \sqrt{h}$$

and approximately $t^2 = \frac{5}{4} h$ and $t = \frac{10}{9} \sqrt{h}$. Hence the rule to find the time in which a conical pendulum will make a revolution: Multiply the square root of the height of the axis taken in feet by 1·11072, or approximately by $\frac{10}{9}$; the product will be the time in seconds.

Thus supposing the height of the axis to be 4 feet: the square root 4 is 2 and 2 × 1·11072 = 2·22144 seconds, the time in which the pendulum will perform one revolution.

Conversely, the time being given, we shall have for the height of the axis,

$$h = {\cdot}81057\, t^2$$

that is: Multiply the square of the time of the revolution in seconds by ·81057, and the result will be the height of the axis in feet. Thus if the time be 2 seconds, then $t^2 = 4$ and 4 × ·81057 = 3·24228 feet.

Similarly it may be found that if the pendulum circulates in a second, its altitude will be ·81057 foot = 9·72684 inches; the altitude corresponding to a half-seconds conical pendulum will be 2·43174 inches, and that answering to a circumvolution in the third of a second is 1.08076 inch.

If n denote the number of revolutions which the pendulum is required to make in a minute, we shall have the analogy

$$t : 60 :: 1 : n, \text{ and therefore } n = \frac{60}{t}$$

But $t = 1{\cdot}11072 \sqrt{h}$, and therefore this value may be substituted for t in the rule $n = \frac{60}{t}$ giving by reduction,

$$n = \frac{54{\cdot}02 \sqrt{h}}{h}$$

That is, to find the number of revolutions which the conical pendulum ought to make per minute for a given height h of axis: Multiply 54·02 by the square root of the given height of axis, and divide the product by the height of the axis taken in feet. Or divide 54·02 by the square root of the height of the axis. These rules are identical, but the first is usually most convenient for calculation.

Example.—Let the height of the axis be 3 ft. 3 ins.: required the number of revolutions which the pendulum ought to make in a minute.

Here h = 3 ft. 3 ins. = 3·25 ft. The square root of 3·25 is 1·80277564, but 1·8 may be taken as sufficiently accurate for practice. Then 54·02 × 1·8 = 97·236, and 97·236 divided by 3·25 gives 29·919 as the number of revolutions which the pendulum ought to make in a minute.

Had we applied our second rule of dividing 54·02 by the square root of the given height, we would have found $\frac{54{\cdot}02}{1{\cdot}8} = 30{\cdot}022$ as the number of revolutions instead of 29·919; the difference arises from the principle explained at p. 229 of Vol. II. in treating of the effect produced upon a fraction by relatively increasing or diminishing its terms. To avoid these discrepancies and to render the rule even more convenient, it may be put under this form:

$$n = \frac{\sqrt{2918{\cdot}1604\, h}}{h} \text{ or simply} = \frac{\sqrt{2918\, h}}{h}$$

which last may be used in all cases where extreme accuracy is not required. In words: Multiply the height of the axis by 2918: extract the square root of the product, and divide this last result by the height of the axis: the quotient will be the proper number of revolutions of the pendulum in a minute.

Thus, taking the same case as before, we have 2918 × 3¼ ft. = 9483·5, the square root of which is 97·383, and this divided by 3¼ = 3·25, gives 29·964 as the number of revolutions.

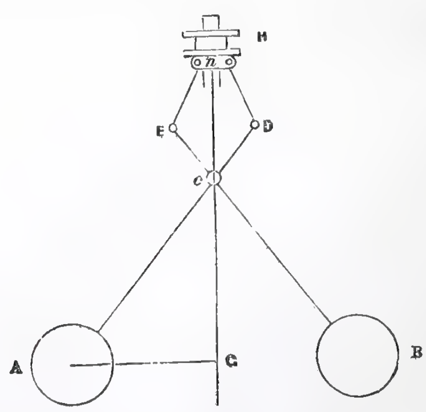
If the number of revolutions per minute be given to find the height of the axis, we have this rule deduced from those preceding:

$$h = \frac{2918{\cdot}1604}{n^2} \text{ or simply} = \frac{2918}{n^2}$$

that is, supposing the last to be sufficiently accurate: Find the square of the given number of revolutions of the pendulum per minute, and divide 2918 by that number: the quotient will be the height of the axis in feet.

Thus, let the number of revolutions be 30: then the square of 30 is 900 and 2918 ÷ 900 = 3·242 ft., the proper height of the axis very nearly.

The conical pendulum has been long known in its application to time-keepers; but its most general application at present is to regulate the admission of the steam to the steam-engine. The form generally adopted for this purpose is that represented in the annexed figure, and which is too



well known to require any technical description; also, from what has been stated above in reference to the simple conical

pendulum, it is easy to form a general idea of the action of the balls A and B upon the sliding collar at H. Thus the centrifugal force being inversely as the square of the time of revolution, if the motion be accelerated, the balls will diverge and shorten their perpendicular distance below the centre C, and consequently pull down the collar H with which they communicate through the rods AD, DH, and BE, EH, thereby shortening the diagonal HC of the parallelogram DE. The collar H acts upon the end of the lever communicating with the throttle valve of the steam engine in various ways, and by various combinations of links. Motion is usually communicated to the axis by a pinion on its lower end.

To determine the relation of the forces developed by the action of the governor, let P be taken to represent the pressure of the extremity of the lever, that is, the pressure which must be applied to it to cause it to change its position vertically; and let S be the strain thereby produced upon each of the rods DH and EH in the direction of its length; and finally, let W represent the weight of each of the balls A and B. We ought also to take into account the weight of the rods; but to render the calculation less complex, let these be assumed in the meantime to be merely rigid lines of connection without weight.

Now, upon each of the rods the following pressures are applied: the weight of the ball and the weight of the rod acting vertically; the centrifugal force of the ball and that of the rod (also assumed to be nothing) acting horizontally; the strain S and the resistance of the axis at C. But if the rods be assumed to be destitute of weight, they must be assumed also to be without centrifugal force, and accordingly that element will fall to be omitted in the calculation. For simplicity let us put v to represent the angular velocity about the centre of motion, the length of the rods AC $= a$, the part from C to D $= b$; the rod $\mathrm{D}n = c$; finally, the angle GCA $= \theta$, and that $\mathrm{C}n\mathrm{D} = \theta'$. We have then the centrifugal force of the ball A, that is the force acting upon it horizontally to impel it from the axis of motion,* expressed by

$$\frac{\mathrm{W}}{g} v^2 \,\mathrm{GA}, \text{ that is, } \frac{\mathrm{W}}{g} v^2 a \sin\theta$$

But the effect of the horizontal force to cause the rod a to turn round the centre C will be expressed by

$$\frac{\mathrm{W}}{g} v^2 a^2 \sin\theta \cos\theta$$

Moreover, the weight of the ball referred to the same centre C is evidently expressed by

$$\mathrm{W}\, a \sin\theta$$

and the strain S also referred to the centre C will be represented by

$$\mathrm{S}\,.\,b \sin(\theta + \theta')$$

Now, that the system may be in equilibrium the momentum of the centrifugal force must be equal to the sum of the weight of the ball and the pressure S—which last will sometimes assist the centrifugal force as when the balls are diverging, and at other times oppose it, as when the balls are converging. We shall therefore have for these conditions the general equation

$$\frac{\mathrm{W}}{g} v^2 a^2 \sin\theta \cos\theta = \mathrm{W}\, a \sin + \mathrm{S}\, b \sin(\theta + \theta')$$

But P is the resultant of the pressures S acting in the direction of the rods nD and nE, and inclined to one another at the angle $2\,\theta'$; it may therefore be found that

$$\mathrm{P} = \tfrac{1}{2}\mathrm{P}\left\{\sin\theta + \cos\theta \tan\theta'\right\}$$

But the sides b and c of the triangle CDn being opposite to the angles θ' and θ, therefore

$$\frac{\sin\theta'}{\sin\theta} = \frac{b}{c} \text{ and } \cos\theta' = \sqrt{\left(1 - \frac{b^2}{c^2}\sin^2\theta\right.}$$

Hence, by substituting these values and reducing, we obtain the general equation

$$\frac{v^2}{g}\mathrm{W}a^2\cos\theta = \mathrm{W}a + \tfrac{1}{2}\mathrm{P}b\left\{1 + \frac{\frac{b}{c}\cos\theta}{\left\{1 - \frac{b^2}{c^2} + \frac{b^2}{c^2}\cos^2\theta\right\}^{\frac{1}{2}}}\right\} \quad \text{(B)}$$

From this equation any one quantity can be determined when the others are given. But it is commonly the case that the length of the rods b and c are equal, and that the angle θ is taken at 30 degrees. Now, the values of b and c must be determined by the length of travel t, which it is proposed to give to the collar H on the spindle, and will be expressed generally by

$$t = 2\,b\cos\theta + c\left(1 - \frac{b^2}{c^2}\sin^2\theta\right)^{\frac{1}{2}}$$

which, on the assumption of $b = c$, becomes

$$t = 2\,b\cos\theta. \quad \text{Therefore } \cos\theta = \frac{t}{2\,b}$$

And on the assumption $b = c$ in equation (B), that expression will be reduced to the very simple form

$$\frac{v}{g}\mathrm{W}a^2\cos\theta = \mathrm{W}a + \mathrm{P}\,b \quad . \quad . \quad . \quad . \quad \text{(C)}$$

Now, if N be the number of revolutions made by the fly-wheel in a second, and n N the number made by the spindle of the governor in the same unit of time, then will $2\,\pi\,n\,\mathrm{N}$ represent the value of v, that is, the space described per second by a point situated at a distance 1 from the axis of the spindle. If then this value be substituted for v in equation (C), we shall have

$$\frac{4\,\pi^2 n^2 \mathrm{N}^2}{g}\mathrm{W}a^2\cos\theta = \mathrm{W}a + \mathrm{P}\,b$$

and from this equation we get

$$\cos\theta = \frac{(\mathrm{W}a + \mathrm{P}b)\,g}{4\,\pi^2 n^2\,\mathrm{W}a^2}$$

And equating the two values of $\cos\theta$, and solving in respect of t, we have

$$t = \frac{b\,g\,(\mathrm{W}a + \mathrm{P}b)}{(2\,\pi^2 n^2 a^2 \mathrm{W})\,\mathrm{N}^2}$$

Now, if $\mathrm{P}\,(1 + \frac{1}{m})$ and $\mathrm{P}\,(1 - \frac{1}{m})$ represent the values of P corresponding to the condition that the collar shall be on the point of motion, and let $\mathrm{N}\,(1 + \frac{1}{n})$ and $\mathrm{N}\,(1 - \frac{1}{n})$ be the corresponding values of N, so that the variations e way of $\frac{1}{n}$th from the mean number N of revolutions may be upon the point of causing the valve to move; if these values of P and N be substituted in the above formula for t, and be equated and reduced, we shall have

$$\frac{\mathrm{W}a}{\mathrm{P}} = \frac{1}{2\,m}\left(n + \frac{1}{n}\right) - 1$$

from which, if the values of P, a, m, n, be assigned, the weight W of the ball will be determined. Thus neglecting $\frac{1}{n}$ as very small when compared with n, we have

$$\mathrm{W} = \frac{\mathrm{P}\,(n - 2\,m)}{2\,m\,a} \quad \text{and } n = 2\,m\left(1 + \frac{\mathrm{W}}{\mathrm{P}}a\right)$$

Thus, let us suppose the value of P to be 100 lbs., that of $m = 10$ lbs., the length of the rod, $a = 4$ ft., and $n = 60$, then $n - 2\,m = 40$, which, multiplied by the value of P $= 100$, gives 4000 as the numerator of the fraction. Again, $2\,m\,a = 2 \times 10 \times 4 = 80$, and 4000 divided by 80, gives 50 lbs. as the weight of the balls.

* The expression $\frac{\mathrm{W}}{g} v2\,\mathrm{GA}$ agrees with the formula (A) at the bottom of page 233, in which R represents GA, the radius of the orbit in which the ball, A, revolves, and v the angular velocity replaces its equivalent $\frac{\mathrm{V}}{\mathrm{R}}$

Again, knowing the weight of the balls to be each 30 lbs., the pressure P upon the collar to be 120 lbs., and that 12 lbs. $= m$, are necessary to be applied in order that the collar may be on the point of sliding, the rod, a, being as before 4 feet, what is the limit of variation in the number of revolutions which is sufficient to give motion to the valve?

$$\text{Here } n = 2\,m\left(1 + \frac{W}{P}\,a\right) = 24\,(1 + \frac{30}{120} \times 4) = 48$$

so that the variation of speed shall not exceed $\frac{1}{48}$ part of the mean number of revolutions of the spindle of the governor in a given time. Thus the mean number of revolutions being 24 per minute, the speed shall be restricted to a variation of $\frac{1}{2}$ of a revolution either way.

We have left out of account the weight of the rods; but if it be desired to include the effect of these in the calculation, it may be done thus: the centrifugal force on the rod A D will manifestly produce the same effect as though its weight were collected in its centre of gravity, which, if the rod be uniform, will be situated at a distance from the centre, C, represented by $\frac{1}{2}\,(a—b)$. Therefore, if w be its weight, its momentum about the centre will be expressed by

$\frac{1}{4}\,\frac{w}{g}\,v^2\,(a—b)^2 \sin\theta \cos\theta$, a quantity which must be added to the momentum of the ball derived from the centrifugal force. Again, the momentum of the weight counteracting the momentum of the centrifugal force, will be $w\,\frac{1}{2}\,(a—b)\sin\theta$, which must in like manner be added to the momentum of gravity of the ball.

TERMS USED IN MECHANICS.

V. CENTRIFUGAL FORCE—ILLUSTRATIONS.

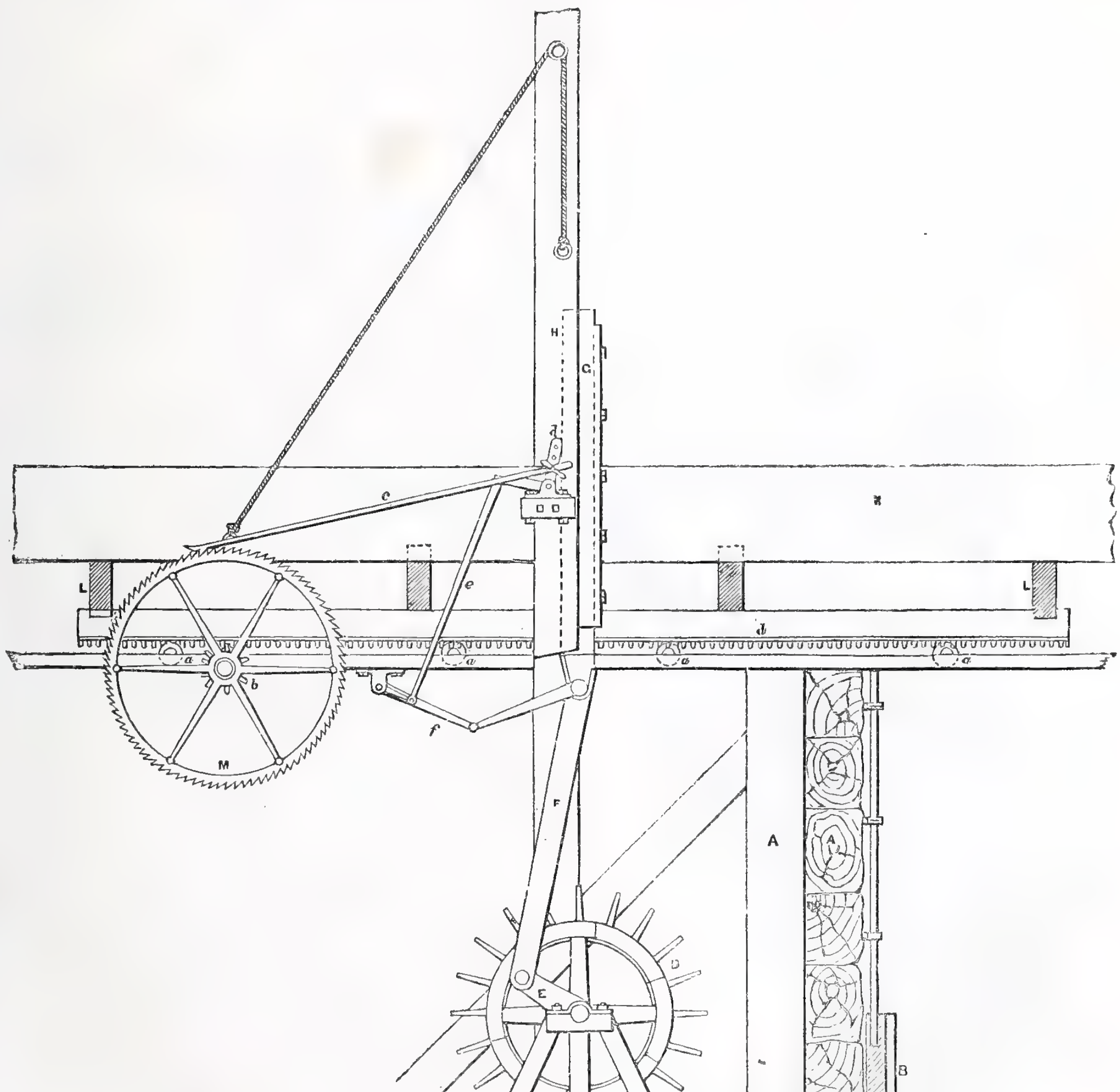
One of the simplest forms of experiment in which the operation of this newly-discovered law of magnetic action is manifested, is the following:—A bar of glass, composed of silicated borate of lead, two inches in length, and half an inch in width and in thickness, is suspended at its centre by a long thread, formed of several fibres of silk cocoon, so as to turn freely, by the slightest force, in a horizontal plane, and is secured from the agitation of currents of air by being inclosed in a glass jar. The two poles of a powerful electro-magnet are placed one on each side of the glass bar, so that the centre of the bar shall be in the line connecting the poles, which is the line of magnetic force. If, previous to the establishment of the magnetic action, the position of the bar be such that its axis is inclined at half a right angle to that line, then, on completing the circuit of the battery so as to bring the magnetic power into operation, the bar will turn so as to take a position at right angles to the same line; and, if disturbed, will return to that position. A bar of bismuth, substituted for the glass bar, exhibits the same phenomenon, but in a still more marked manner. It is well known that a bar of iron placed in the same circumstances, takes a position coincident with the direction of the magnetic forces; and therefore at right angles with the position taken by the bar of bismuth subjected to the same influence. These two directions are termed by the author *axial* and *equatorial;* the former being that taken by the iron, the latter that taken by the bismuth. Thus it appears that different bodies are acted upon by the magnetic forces in two different and opposite modes; and they may accordingly be arranged in two classes: the one, of which iron is the type, constituting those usually denominated *magnetics;* the other, of which bismuth may be taken as the type, obeying a contrary law, and therefore coming under the generic appellation of *diamagnetics.* The author has examined a vast variety of substances, both simple and compound, and in a solid, liquid, or gaseous form, with a view to ascertain their respective places and relative order with reference to this classification. As no gaseous body of any kind, or in any state of rarefaction or condensation, affords the slightest trace of being affected by magnetic forces, gases may be considered as occupying the neutral point in the magnetic scale, intermediate between magnetic and diamagnetic bodies. The magnetic properties of compound bodies depend on those of their elements; and the bodies are rendered either magnetic or diamagnetic according to the predominance of one or other of these conditions among their constituent parts. In one respect, the diamagnetic action presents a remarkable contrast with the magnetic; and the difference is not merely one of degree, but of kind. The magnetism of iron and other magnetics is characterised by polarity: that of diamagnetics is devoid of any trace of polarity: the particles of two bodies of the latter class, when jointly under the influence of the magnetic forces, manifesting towards each other no action whatever, either of attraction or repulsion. It has long been known that the magnetism of iron is impaired by heat; and it has been generally believed that a certain degree of heat destroys it entirely. The author finds, however, that this opinion is not correct; for he shows that, by applying more powerful tests than those which had been formerly confided in, iron, nickel, and cobalt, however high their temperature may be raised, still retain a certain amount of magnetic power, of the same character as that which they ordinarily possess. From the different temperatures at which the magnetic metals appear to lose their peculiar power, it had formerly been surmised by the author that all the metals would probably be found to possess the same character of magnetism, if their temperature could be lowered sufficiently; but the results of the present investigation have convinced him that this is not the case, for bismuth, tin, &c., are in a condition very different from that of heated iron, nickel or cobalt. The magnetic phenomena presented by copper and a few other metals are of a peculiar character, differing exceedingly from those exhibited by either iron or bismuth, in consequence of their being complicated with other agencies, arising from the gradual acquisition and loss of magnetic power by the iron core of the electro-magnet, the great conducting power of copper for electric currents, and its susceptibility of being acted upon by induced currents of magneto-electricity, as described by the author in the first and second series of his researches. The resulting phenomena are to all appearance exceedingly singular and anomalous, and would seem to be explicable only on the principles referred to by the author. Pursuing his inductive inquiries with a view to discover the primary law of magnetic action from which the general phenomena result, the author noticed the modifications produced by different forms given to the bodies subjected to experiment. In order that these bodies may set either axially or equatorially, it is necessary that their section, with reference to the plane of revolution, be of an elongated shape: when in the form of a cube or sphere they have no disposition to turn in any direction: but the whole mass, if magnetic, is attracted towards either magnetic pole; if diamagnetic, is repelled from them. Substances divided into minute fragments, or reduced to a fine powder, obey the same law as the aggregate masses, moving in lines which may be termed *diamagnetic curves,* in contradistinction to the ordinary magnetic curves, which they everywhere intersect at right angles. These movements may be beautifully seen by sprinkling bismuth in very fine powder on paper, and tapping the paper while subjected to the action of a magnet. The whole of these facts, when carefully considered, are resolvable, by induction, into the general and simple law, that while every particle of a magnetic body is attracted, every particle of a diamagnetic body is repelled, by either pole of a magnet. These forces continue to be exerted so long as the magnetic power is sustained, and immediately cease on the cessation of that power. Thus do these two modes of action stand in the same general antithetical relation to one another as the positive and negative conditions of electricity, the northern and southern polarities of ordinary magnetism, or the lines of electric and of magnetic force in magneto-electricity. Of these phenomena, the diamagnetic are the most important, from their extending largely, and in a new direction, that character of duality which the magnetic force was already known, in a certain degree, to possess. All matter, indeed, appears to be subject to the magnetic force as universally as it is to the gravitating, the electric, the cohesive, and the chemical forces. Small as the magnetic force appears to be in the limited field of our experiments, yet when estimated by its dynamic effects on masses of matter, it is found to be vastly more energetic than even the mighty power of gravitation, which binds together the whole universe: and there can be no doubt that it acts a most important part in nature, and conduces to some great purpose of utility to the system of the earth and of its inhabitants. Towards the conclusion, the author enters on theoretical considerations suggested to him by the facts thus brought to light. An explanation of all the motions and other dynamic phenomena consequent on the action of magnets on diamagnetic bodies might, he thinks, be offered on the supposition that magnetic induction causes in them a state the reverse of that which it produces in magnetic matter: that is, if a particle of each kind of matter were placed in the magnetic field, both would become magnetic, and each would have its axis parallel to the resultant of magnetic force passing through it; but the particle of magnetic matter would have its north and south poles opposite to, or facing the contrary poles of the inducing magnet; whereas, with the diamagnetic particles, the reverse would

obtain; and hence there would result, in the one substance, approximation; in the other, recession. On Ampère's theory this view would be equivalent to the supposition that, as currents are induced in iron and magnetics, parallel to those existing in the inducing magnet or battery wire, so, in bismuth and other diamagnetics, the currents induced are in the contrary direction. So far as experiment yet bears upon such a notion, the inductive effects on masses of magnetic and diamagnetic metals are the same.

AMERICAN SAW-MILL.

The annexed figure, with description, of a saw-mill used in America, is taken from the 6th volume of the Professional Papers of the Royal Engineers. The power is supplied by a fall of water, which is easily obtained upon the numerous streams with which the country is intersected. The principle of the machine is very simple, and will be rendered obvious by the following description :—

A, the dam, formed very commonly of squared logs resting against a standard strutted from the rear, provision being of course made to carry off the surplus water; B, is the sluice, which, when it is wanted to work the saw, is raised, and admits the water into the trough C, to the wheel, D, which is generally made of small diameter, in order that the velocity of the water may give it as many revolutions as possible consistent with the necessary power, and thus enable the saws to make as many strokes as the wheel makes revolutions. E, crank, on the wheel-shaft, to which is fixed the connecting-rod F, which is fixed to the bottom of the saw



frame G, which runs up and down between the standards H, being impelled by the connecting-rod. K, is the log to be cut, mounted on the frame L, which has a rack, *d*, fixed on its under side, and is supported by rollers, *a*. The pinion, *b*, on the axis of the ratchet-wheel, M, works in the rack, and according as the wheel moves forward or backward the frame moves towards or away from the saws. The wheel is moved by the pall, *c*, the other end of which is pinned to the lever, *d*. This lever is moved by the rod, *e*, moved by the double lever, *f*, jointed to the frame of the building and to the saw-frame. To reverse the motion after the log is cut, the pall is lifted out of gear with the wheel, and the latter turned in the opposite direction by hand. In these simple mills, where the

frame is fixed at once to the shaft of the water-wheel, there are seldom more than two saws at work at once, but the principle, of course, can be extended at pleasure.

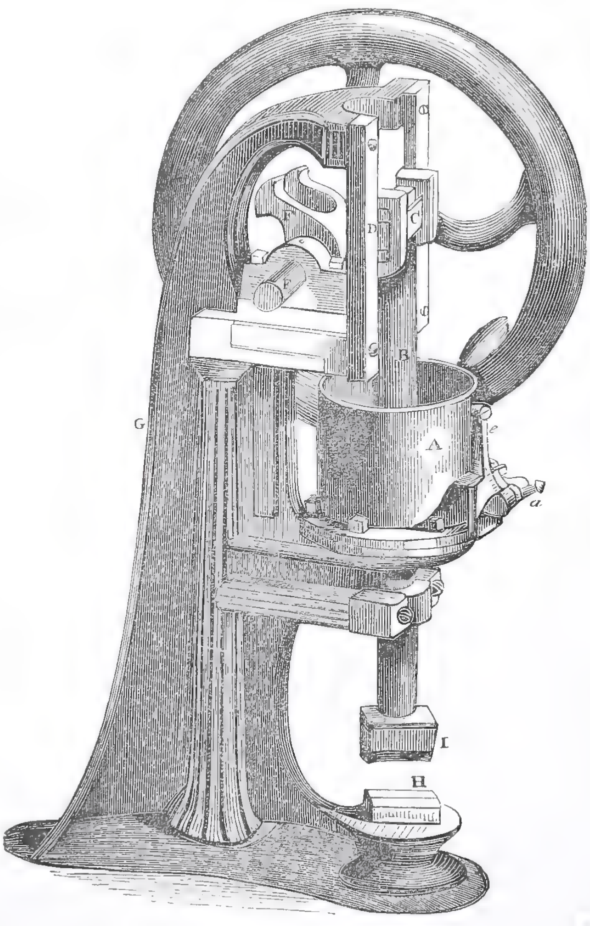
We believe a saw-mill of this simple construction would be found exceedingly useful in remote localities, where it could readily be erected upon a running water at a small outlay of capital, and could answer all that would be wanted of it; but especially in our colonies, where the facilities and means of providing more elaborate and expensive machinery could not be so available as at home. The structure of the mill now illustrated is so simple, that an ordinary carpenter could be at no loss to erect a mill of a similar kind. A jobbing smith could furnish the iron fittings about it; indeed, these could, in cases of need, be made of hardwood, which, we believe, has actually been done.

HUGHES' PATENT TRIP HAMMERS.

The annexed engravings represent an improvement in Trip Hammers, for which a United States patent was granted to Bernard Hughes, of Rochester, N. Y., on the 16th of May, 1854, and since that period patents have been taken out in Europe.

Fig. 1 is a perspective view; fig. 2 a vertical section

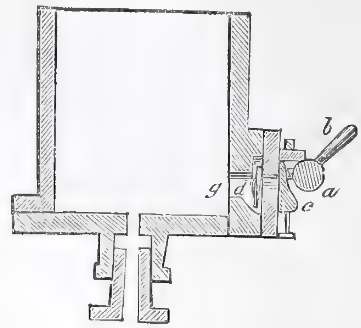
Fig. 1.



through the atmospheric cylinder, showing one of the regulating valves; and fig. 3 is a broken vertical section through the cylinder, showing a second regulating valve. Similar letters refer to like parts.

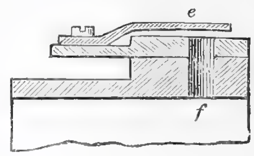
The nature of the invention consists in providing the rod of the hammer with a piston, fitting and working in a cylinder, which is so constructed and furnished with valves, that the air may be excluded from under the piston, and admitted in such a manner and in such a degree, as to control the force of the blow of the hammer at the pleasure of the operator; also to increase the force of the blow independent of the weight of the hammer.

Fig. 2.



The machinery is erected on, and secured to, a strong and neat iron frame. H is the anvil; I is the hammer, secured to a vertical rod or shaft, B, which is furnished at the top part with a trip block at each side, which have slides running in guide grooves in the two upright standards, D, which are firmly secured to the head and to a block of the frame, G, by bolts and screws; E is the driving shaft, with a fly-wheel on it at one side, and double toes or trippers, F, at the middle, which, as the shaft, E, is revolved, rotate between the standards, D, and lift up and let go the trip blocks, C, and, consequently, the hammer, giving to the latter its up and down reciprocating motion. On the hammer rod, B, is a piston, fitting air-tight into the cylinder, A, which is open at the top, but closed at the bottom, the rod, B, working through an air-tight stuffing-box in the bottom, as will be understood by referring to fig. 2. On the side of this cylinder is a valve-box having two valves, the one, *c*, fig. 2, to allow air to pass from the outside to the inside of cylinder A; and the other, *e*, fig. 3, to allow air to pass from the inside out from under the piston. By the working of these two valves, the useful effects stated, as comprising the nature of the invention, are obtained. The valve which allows the air to pass out of the cylinder, is a nicely suspended spring-plate valve, *e*, hung on a stud, fig. 3, covering the passage, *f;* it is cushioned on its inner surface. When the piston is working with the small slide valve, *c*, closed, the full pressure of the atmosphere is obtained on the piston. The tendency of the valve, *e*, is to open outward when the piston descends; consequently, as the piston is raised, a vacuum is created under it in the cylinder, and the air then presses on the outside of the plate valve, *e*, pressing it against the face of the box, and closing the port or passage, *f*. Working in this manner, with a vacuum of fifteen lbs. on the square inch, and with a piston of only twelve inches diameter, the pressure would be 565 lbs. added to the weight of the hammer, with an increased velocity of motion. To regulate the blow and graduate its force, there are bearings secured on the sides of the valve-box, and a small transverse roller shaft, *a*, fig. 2, is secured in them. On this roller is a small stud for lifting the projection of the slide valve, and raising it to admit air through the passage, *g;* this small slide valve is kept in its seat by a spring secured to its bottom, and it can only be raised upwards; *d* is a small flap valve opening inwards in the passage, *g*. Supposing valve, *c*, fig. 2, to be open, and the valve, *e*, fig. 3, to be completely closed, no air could pass out of the cylinder, A, consequently it would be impossible to strike a blow upon the anvil because of the resistance of the air (it requiring to be compressed) under the piston. But if we suppose the inlet slide valve, *c*, and the outlet valve, *e*, to be so regulated as to admit different quantities of air into and out of the cylinder during each stroke, then any force of blow in the whole scale—from the maximum to the minimum—can be given, because the resistance can be regulated at will. This is done by a cam toe on the roller, *a*, fig. 1, set in front of valve *e*, and which.

Fig. 3.



by turning handle, *b*, can close the said valve entire, or so much of it as to allow the exact quantity of air to escape as is desired. By operating the handle, *b*, the slide valve, *c*, is raised, and the valve, *e*, actuated at the same time. By this method of operating these valves, an experienced attendant can graduate one blow, so as to strike its full force, and the next one to come down so gently upon the anvil, as to touch an egg and not crack it.

This trip hammer is very compact, occupying but a very small space; it gives a true vertical blow, and, when made to work with a vacuum at about fourteen lbs. pressure on the inch, there is always a cushion of air under the piston to make it start freely at the end of each stroke. Hammers of this kind have been in operation for nearly a twelvemonth, and their qualities have been fully tested. Four different sizes are manufactured, so as to adapt them for heavy and light work—for forging iron and steel, and for hammering brass, tin, and copper, by tin and copper smiths.

INORGANIC CHEMISTRY.

CHAPTER VI.

Qualitative Analysis (*Continued*).

DETECTION OF ACIDS IN A COMPLEX SUBSTANCE, SOLUBLE IN WATER.

Examine the solution with test paper. If neutral, neither carbonates nor soluble sulphurets are present. If it redden litmus paper, this may arise either from a free acid, or from the presence of certain neutral metallic salts. In the latter case, the turbidity produced by adding a drop of an alkaline liquid is permanent. In the former, it disappears on agitation, and the solution is then to be neutralized with caustic potash. If alkaline, alkalies may be present, in the caustic state, or combined with carbonic acid, silicic acid, or sulphur. Heat a part of the solution, and neutralize with hydrochloric acid. If *effervescence* arise, the gases given off are examined, separating carbonic and sulphurous acids by means of peroxide of lead, which absorbs the latter. If a precipitate falls, filter, wash, dry, and test for silica. Nitrate of baryta is now poured into a concentrated neutral solution of the substance, as long as anything is precipitated. Filter and wash the precipitate, which may contain sulphuric, sulphurous, arsenic, arsenious, phosphoric, boracic, iodic, and hydrofluoric acids. The precipitate is digested in hydrochloric acid; sulphurous acid, if present, is manifested by its odour. Verify by usual tests. Evaporate the remainder to dryness; treat the residue again with hot hydrochloric acid, dilute with water, and filter. *Sulphate* of baryta and *silicic* acid may remain undissolved. Test original solution. The portion dissolved in hydrochloric acid is now treated with sulphuretted hydrogen, when iodine is precipitated, if iodic acid was present, and sulphuret of arsenic, in case of *arsenious* or *arsenic* acids. Test original solution. *Phosphoric*, *hydrofluoric*, and *boracic* acids may remain unprecipitated, and are tested for; the first in the muriatic solution, the second in the original liquid; the last in the original dry substance. To the clear liquid, after the precipitate caused by nitrate of baryta has been filtered off, nitrate of silver is added. The precipitate, if any, is treated with ammonia, and filtered. If a solid yellow body remains, it is iodide of silver, indicating *iodine*. Test original solution as above. The clear liquid is treated with nitric acid in excess. A white precipitate shows *hydrochloric* acid or *chlorine*. Under certain circumstances, *arsenious*, *arsenic*, and *boracic* acids may remain in the liquid, the method of testing for which has been already given. The only acids not precipitated by nitrate of silver are the *nitric* and *chloric*. Test the original substance.

ANALYSIS OF A COMPLEX BODY, CONTAINING THE SAME ELEMENTS AS ABOVE, BUT INSOLUBLE IN WATER.

The substance in question is first treated with water, and if any portion is dissolved it is examined as above. The residue is then treated with nitric, muriatic, or nitro-hydrochloric acids, as may be deemed best, after trial with a small fragment, heat being applied if necessary. Alloys, which fall under this head, are, for the most part, soluble in nitric acid.

The acid liquid is first treated with sulphuretted hydrogen, and the precipitate digested with hydrosulphate of ammonia, which dissolves the sulphurets, answering to oxide of gold, protoxide and peroxide of tin, oxide of antimony, and arsenic acid, if present. For methods of separating and distinguishing these metals, see above. The portion, if any, undissolved by hydrosulphate of ammonia, may contain oxides of cadmium, lead, bismuth, copper, silver, and both oxides of mercury. Test for these as above.

If the remaining liquid, after treatment with sulphuretted hydrogen, still contain any fixed bases, ammonia is added in slight excess, and then hydrosulphate of ammonia. The precipitate may represent ferric and ferrous oxides, oxides of cobalt, nickel, zinc, manganese, alumina, and in certain cases (if phosphoric or boracic acids are present) magnesia, lime, strontia, and baryta. The precipitate is digested in aquaregia. If a precipitate is produced by adding dilute sulphuric acid, baryta, strontia, and possibly lime, are present. Test as above. Add excess of ammonia to the liquid which remains after the sulphates have been filtered off. Alumina, peroxide of iron, and magnesia (if phosphoric acid be present) are precipitated. Boil in potash, which dissolves the *alumina*, which may be reprecipitated by muriate of ammonia. Magnesia and peroxide of iron may be separated by adding ammonia to the liquid in very slight excess, and then succinate of potash, which throws all the *iron*, whilst *magnesia* remains in solution. The liquid filtered from the ammoniacal precipitate, may contain oxides of nickel, cobalt, manganese, and zinc. Separate and test as above. If the liquid still contain any fixed bases, the investigation is carried on as in former sections.

The detection of the acids is frequently less easy in this case than in substances soluble in water. Treat a portion of the solid substance with hydrochloric acid. If effervescence arises, carbonic or hydrosulphuric acid, or both, may be present. Test the evolved gases with lime, water, and acetate of lead. Dissolve another portion of the substance in hydrochloric acid, except silver, lead, or protosalts of mercury are present, when nitric acid must be used. Add nitrate of baryta or chloride of barium, according to the acid employed. *Sulphuric* acid is shown by a white precipitate. If, on heating a part of the compound in nitric acid, red fumes are evolved, whilst the diluted liquid afterwards gives a white precipitate with nitrate of baryta, the substance is a *sulphuret*. Another portion is dissolved in nitric acid, and nitrate of silver added. A white precipitate shows the presence of *chlorine*. If chlorine is suspected in the form of subchloride of mercury, digest a portion in perfectly pure potash; filter, saturate the clear liquid with nitric acid, and test with nitrate of silver. The substance is next tested in the usual manner for *boracic*, *nitric*, and *arsenic* acids. After having ascertained the absence of arsenic acid, sulphuric acid, sulphur, and boracic acid, the substance may be examined with the blowpipe for *phosphoric* acid. Otherwise, if the base be one of those precipitated by SH, the clear liquid remaining after application of that reagent, is well boiled and tested in the usual manners. If the base be one precipitable from ammoniated solutions by hydrosulphate of ammonia, the residual liquid, heated with muriatic acid (or nitric, if nitrate of silver is to be used) until all odour of sulphuretted hydrogen has disappeared, is taken for examination.

If the bases be earths and earthy alkalies, along with metals of the former class (precipitable by SH), these oxides are removed from the acid solution by its aid, and ammonia added to precipitate the earths combined with the phosphoric acid. If baryta, strontia, and lime only be present, a precipitate, on the addition of ammonia, gives strong reason to admit the presence of phosphoric acid. This is confirmed by ascertaining the absence of boracic acid, and using the blowpipe. If alumina be present, the precipitate must be dissolved in a very little nitric acid, nitrate of silver added, and the liquid then cautiously neutralized with ammonia until a yellow precipitate appear.

But if oxides of the second class (precipitable by hydrosulphate of ammonia) be found along with the earths, the substance is first dissolved in muriatic acid (or nitric, if nitrate

of silver is to be employed), treated with sulphuretted hydrogen to remove any base of the first class, heated to expel all traces of that gas, and dilute sulphuric acid added to precipitate baryta and strontia. If alcohol be poured in, the same reagent will precipitate the lime also. The precipitate is then filtered off, and the alcohol expelled by heat. If neither alumina nor magnesia be present, but only oxides of the second group, they are precipitated with ammonia and hydrosulphate of ammonia, and the clear remaining liquid tested for phosphoric acid. Should alumina or magnesia be present, no hydrosulphate of ammonia is added, but an excess of pure potash, and the whole liquid is then boiled. The liquid is then filtered off from the precipitate, a part of it treated with hydrochloric acid in excess, chloride of barium added to remove any sulphuric acid present, the liquid filtered, and ammonia added. If phosphoric acid be present, phosphate of baryta is thrown down. Should oxide of zinc and alumina be present, the potash solution is treated with hydrosulphate of ammonia, which removes the zinc. The liquid is filtered off, and heated with muriatic acid to decompose the hydrosulphate; the phosphate of alumina is then precipitated by an excess of ammonia, and the precipitate examined as above.

Substances insoluble in water may likewise be ignited in a porcelain crucible with a large excess of an alkaline carbonate. If water is now added to the residue, the whole is separated into two portions. The solution contains the acids in union with the potash or soda employed; the insoluble residue contains the bases, either alone, as carbonates, or in case of gold, &c., reduced to the metallic state. This latter portion is dissolved in nitric or muriatic acid, and examined as above. The watery solution will contain the acids, which are determined in the usual manner, and alumina, if present. To detect this base, a part of the solution is gradually saturated with an acid, which redissolves the precipitate at first produced. Ammonia is now added, and precipitates the alumina, in company with arsenic and phosphoric acids, if present.

Oxide of mercury cannot be detected in this method, as it is reduced and driven off. Nitric and carbonic acids also must be sought in a separate portion of the original substance.

ANALYSIS OF COMPLEX BODIES CONTAINING THE SAME ELEMENTS, INSOLUBLE IN WATER AND ACIDS.

These can only be sulphates of baryta, strontia, lead, lime, and chloride of silver. The substance is first ignited with an excess of carbonate of soda, in a platinum or porcelain crucible (the latter, if lead or silver be suspected), the residue extracted with water, acidulated with nitric acid, and tested for sulphuric acid and chlorine. The residue, containing carbonates of the bases, and possibly metallic silver, is dissolved in nitric acid (or muriatic, if silver and lead be absent), and the solution tested.

ANALYSIS OF A COMPLEX BODY WHICH MAY INCLUDE ALL KNOWN INORGANIC SUBSTANCES.

Such a body cannot, strictly speaking, occur, since certain combinations mutually exclude each other, and are never simultaneously present. The substance is first extracted with water, and the liquid treated with muriatic acid (or nitric), as laid down above. If, on heating a strong solution with muriatic acid, chlorine is evolved, the liquid may contain peroxides of manganese or cerium, manganic, vanadic, chromic, or selenic acids. By continuing the process until all evolution of gas ceases, they are converted into protoxides of manganese or cerium, chromic oxide, selenious or vanadious acids, which may then be detected in the liquid. Chlorates, combinations of chlorites and chlorides, bromates and iodates, may likewise evolve chlorine when heated with muriatic acid.

On adding an acid to the liquid, a precipitate is sometimes formed, consisting of some feebler acid set free. Such precipitates are generally redissolved by an excess of nitric or muriatic acid, yet tantatic, titanic, and tungstic acids form an exception. The two latter may be recognized by means of the blowpipe. Silicic acid is also precipitated in the same manner, and may be detected by the blowpipe.

If soluble sulphosalts (double sulphurets) are present, they are generally decomposed by muriatic acid. Sulphuretted hydrogen is given off, and an insoluble sulphuret precipitate, which may then be examined.

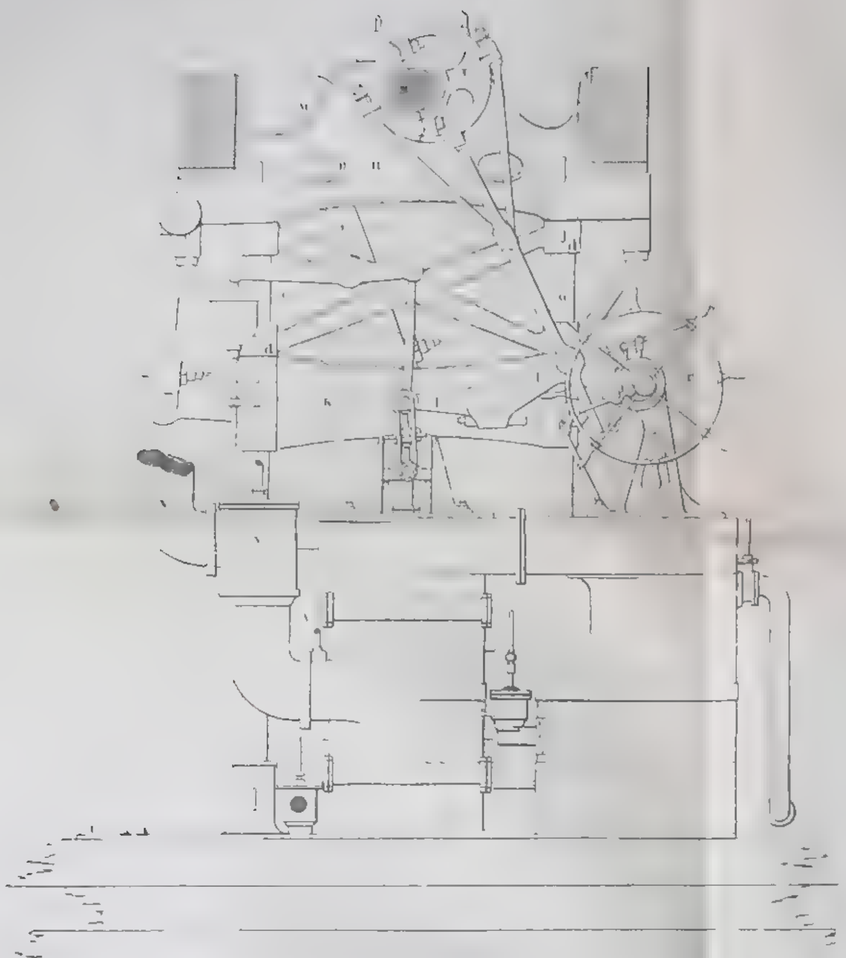
The liquid is next treated, as in the former cases with SH. Besides the oxides of the first class mentioned above, and arsenic and arsenious acids, the precipitate may contain oxides of rhodium, iridium, osmium, palladium, platinum, molybdenum, osmic, antimonic, antimonious, molybdic, tellurous and selenous acids. Before filtering, the solution should be gently heated and allowed to stand for some time. The following substances, though not precipitated themselves by SH, decompose it, and cause a deposit of sulphur—sesquioxides of manganese and iron, manganic, chromic, chloric, bromic, iodic, hyposulphuric, permanganic, and sulphurous acids.

The precipitate is next treated with hydrosulphate of ammonia, which dissolves the sulphurets of platinum, iridium, gold, tin, antimony, molybdenum, tungsten, vanadium, tellurium, selenium and arsenic. The solution is diluted with water, and muriatic acid added until the liquid has a slightly acid reaction. *Platinum* and *iridium* are sought for in the solution by the ordinary tests. A portion of the precipitate formed by muriatic acid in the hydrosulphate solution is examined by the blowpipe for *molybdenum.* Milkiness on addition of water, and a white precipitate on adding alcalies indicate *tellurium.* Confirm with blowpipe. *Selenium* is detected by the blowpipe, or by the ordinary reagents. *Arsenic,* —blowpipe; the methods of discriminating between arsenic and arsenious acids have been given above. The detection of *gold, tin,* and *antimony* has been already indicated.

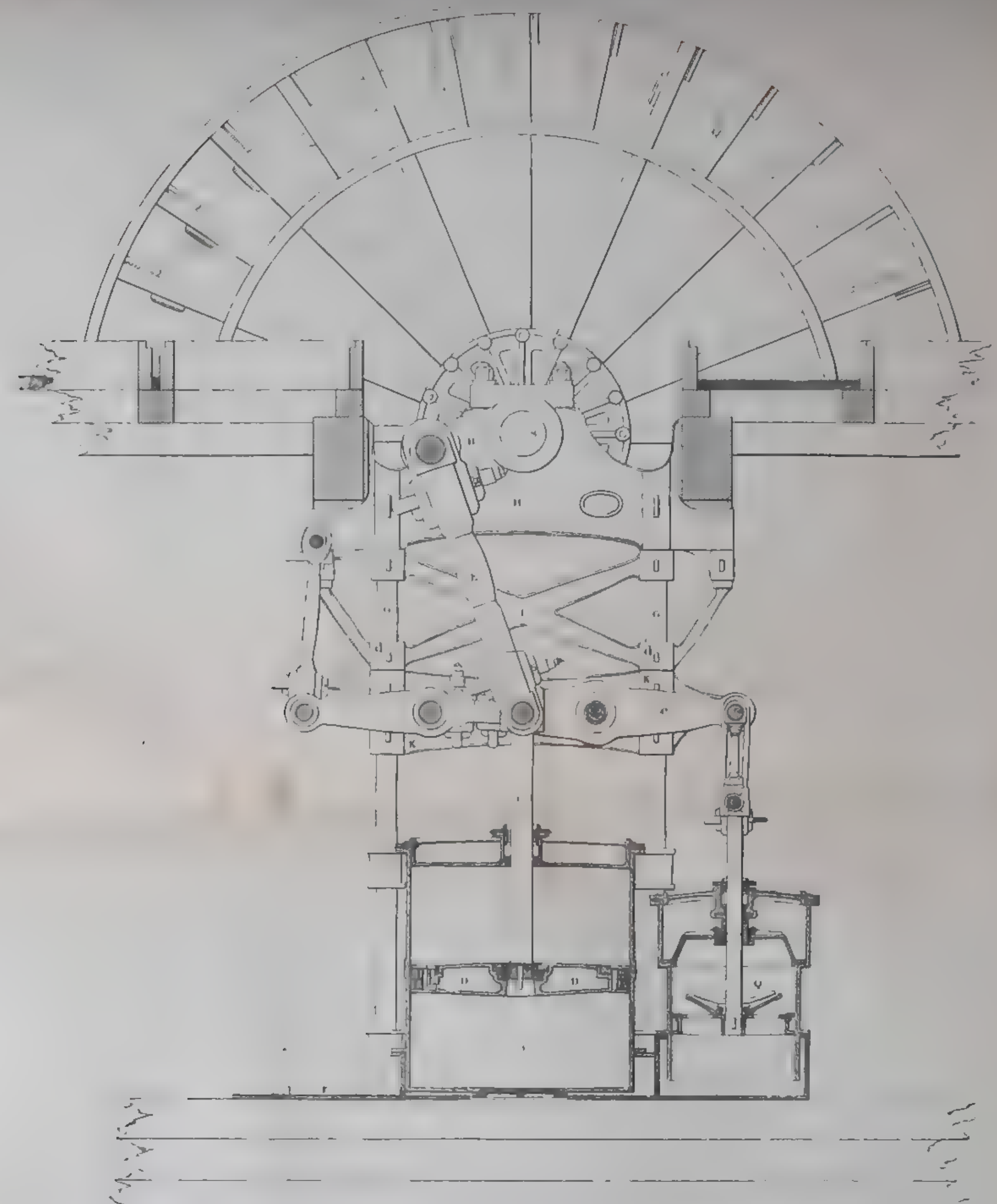
The sulphurets not soluble in hydrosulphate of ammonia, are those of cadmium, lead, bismuth, copper, silver, mercury, palladium, rhodium, osmium. The method of ascertaining the first six has been given; *palladium* is detected by cyanide of mercury; *rhodium,* by yielding a yellow mass when a little of the original substance is fused with bicarbonate of potash, and *osmium,* by its odour when heated with nitric acid. The residual liquid is treated with ammonia and hydrosulphate of ammonia as before. The sulphurets of manganese, iron, zinc, cobalt, nickel, and uranium are precipitated. The treatment of the former five has been given. *Uranium* is detected by dissolving the sulphuret in nitric acid, and adding ammonia, which gives a yellow precipitate.

Besides the above sulphurets, the precipitate may contain the following bases: alumina, glucina, thorina, yttria, zirconia, ceric and chromic oxides, titanic and tantalic acids. The detection of *alumina* in this precipitate has been described. The precipitate is now dissolved in nitric acid, and pure potash in excess added, the liquid having first been heated to expel SH. The solution may contain *alumina, glucina,* and oxide of *zinc.* Muriate of ammonia precipitates the two former, and the latter may then be detected in the clear liquid. Excess of carbonate of ammonia dissolves the *glucina,* leaving the alumina untouched. Apply also blowpipe. The portion insoluble in potash is digested in carbonate of ammonia in excess, which dissolves *thorina, yttria, zirconia,* and *ceric oxide.* These bases are then examined by the usual tests. *Titanic acid,* if present, is detected by the blowpipe, and the action of zinc. *Tantalic acid* cannot be present, as shown at the commencement of this section. *Chromium* is detected by submitting the hydrosulphate precipitate to the blowpipe. The liquid filtered off from the hydrosulphate of ammonia precipitate may contain magnesia, lime, strontia, baryta, soda, potash, and lithia. The detection of all has been given except the last. A portion of the solution is diluted and carbonate of ammonia added, which precipitates lime, baryta, and strontia. To the filtered liquid phosphate of soda is added. If a precipitate falls, lithia, or magnesia, or both, may be present. Another part of the liquid filtered from the earthy carbonates, is evaporated to dryness, and ignited. The mass, if it contains magnesia as sulphate, dissolves in water; otherwise, a little sulphuric acid is added, the mass again slightly ignited, dissolved in a little water, and caustic potash added, which precipitates magnesia, but not lithia. If a precipitate falls, another portion is tested with phosphate of soda. In presence of lithia and magnesia, the detection of potash and soda is difficult. If lithia alone is present, a part of the liquid is dried and ignited as above; the

DIRECT-ACTING ENGINES BY MESS^RS WILLIAM FAIRBAIRN & C^O LONDON.



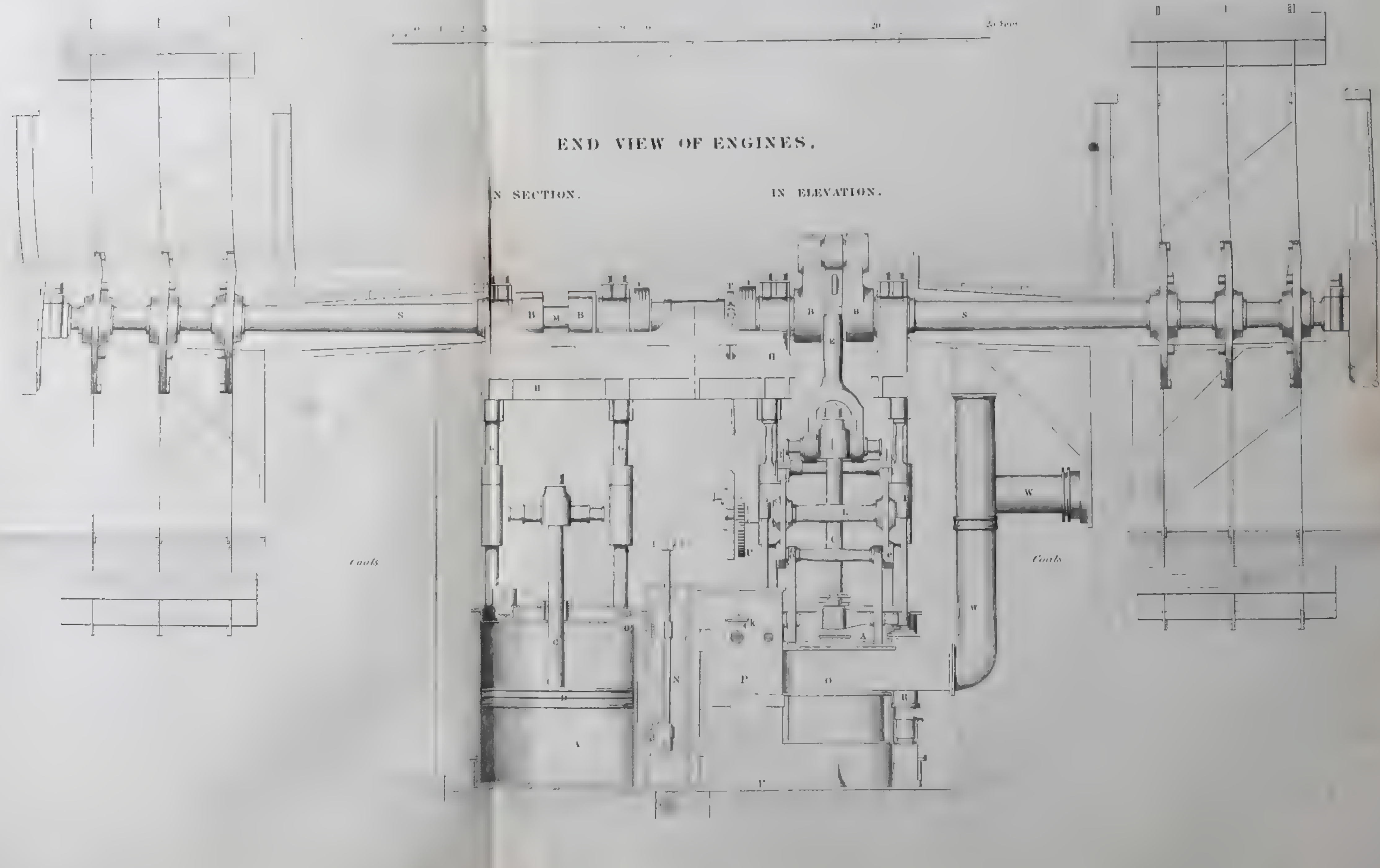
SIDE ELEVATION



SECTIONAL ELEVATION

END VIEW OF ENGINES.

IN SECTION. IN ELEVATION.



residue dissolved in very little water, and tested in the usual manner for potash and soda. If magnesia also is present, the bases are converted into sulphates, the excess of acid expelled by moderate ignition, the residue dissolved in water, and acetate of baryta added in excess. The filtered liquid contains acetates of magnesia, baryta, and the alkalies. The solution, evaporated to dryness, is ignited in a platinum crucible. The residue contains carbonates of baryta and magnesia, insoluble in water, which dissolves out and separates the alkalies.

DETECTION OF ACIDS.

Along with the acids, we shall treat of elementary bodies capable of combining with metals. The presence of certain acids has been indicated at earlier stages of the investigation.

To detect the volatile acids, a part of the substance in fine powder is drenched with sulphuric acid in a test-tube, and gently heated. The evolution of a volatile acid is manifested by the white cloud formed on holding over the liquid a rod dipped in ammonia. The acids thus expelled, in an entire or a decomposed state, are *sulphurous*, known by its odour, *hyposulphuric* and *hyposulphurous*, which both give off sulphurous acid gas when treated with other acids; *nitric* acid, *nitrous* acid, *chloric*, *bromic*, *carbonic* and *oxalic* acids. Strong sulphuric acid evolves also muriatic acid from *chlorides*, a mixture of bromine; hydrobromic and sulphurous acids from *bromides;* purple vapours of iodine from most *iodides;* hydrofluoric acid from *fluorides;* the same acid mixed with fluosilicic acid from the *silicofluorides;* the same mixed with fluoboric acid from the *borofluorides;* sulphuretted hydrogen, or sulphurous acids, from the *sulphurets.*

Most of these acids may be recognised by the tests already stated, but the following additional remarks may be useful. The odour of sulphurous acid cannot be perceived if the sulphite under decomposition is mixed with a nitrate, chlorite, or sulphuret. If sulphites and sulphurets exist together, their odours neutralize each other. With hyposulphates and hyposulphites the case is similar. A hyposulphite mixed with a soluble sulphuret, is detected by adding to the solution a neutral salt of zinc in excess. The hyposulphite alone remains in solution, and on adding muriatic acid, the odour of sulphurous acid is given off. Chlorates, bromates, and iodates, give off oxygen when heated in a tube.

If the addition of sulphuric acid has evolved no volatile acid, the combination may contain iodic, phosphoric, phosphorous, hypophosphorous, boracic and silicic acids, besides others, whose detection has been indicated along with that of the bases. *Selenic* acid evolves chlorine, if heated with muriatic acid, and the residual selenious acid is precipitated by sulphuretted hydrogen as sulphuret of selenium. The detection of *iodates* is easy, as they are reduced by heat into iodides.

Phosphites and *hypophosphites* precipitate subchloride of mercury, if added to an excess of solution of chloride of mercury containing a little muriatic acid.

The part of the substance insoluble in water (or the whole as the case may be) is next examined. It is dissolved in muriatic acid, nitric acid, or aquaregia. When heated in muriatic acid, chlorine is evolved by chromates, seleniates, vanadiates, sesquioxides of cerium and manganese, peroxides of manganese, cobalt and nickel, red lead, and peroxide of lead.

The acid solution is treated as in the former cases.

THE STEAM-ENGINE:

BEING NOTES, HISTORICAL AND PRACTICAL, ON THE STATIONARY, LOCOMOTIVE, AND MARINE ENGINE.

As introductory to the practical study of any department of mechanism, notes detailing the history of its progress are always valuable. Pointing out the various stages in its onward march to perfection, they may be looked upon as the finger-posts of experience, set up by those who have acted as the pioneers of discovery, to guide those coming after them through the mazes of the pathway, to warn them of hidden dangers, and to point out the speediest way of reaching the desired goal.

It is difficult, indeed, to estimate the value of the records of mechanical invention to those particularly interested in its progress. A brilliant discovery or an ingenious invention comes intuitively to no man, though to an unthinking mind it may appear to do so. It is just as much the result of foregone thought and laborious study, as the marble statue in all its loveliness is the result of the intense application and the continued chisellings of its sculptor, although an untutored savage might, on seeing it first uncovered, deem it evoked merely by his will.

Note diligently the history of Newton, Watt, Arkwright, and a host of others, whose names are written on the imperishable roll of fame, and you will find that the brilliant emanations of their genius were the result of patient investigation and laborious study. If they reached a point of perfection in their onward progress quickly—so quickly as to make some think they had done so without any labour—they owed that to their untiring energy and unflinching activity; but they, nevertheless, had to overcome the difficulties which beset them at the outset of their career, and, like other men of lower fame, had to "begin at the beginning." Laying with steady purpose the foundation, the superstructure of their fame proved as lasting as it is noble. Their genius was not the meteor flash which for but a moment illumes the gloom, leaving it dark as ever, or the spark which glitters and expires; it was a steady light, fed from a true, and, consequently, never-failing source, and which has sent down, and will send down, through the mist of time, rays which will guide hosts of their humble followers in the paths of science.

Consider well the importance of this same "beginning at the beginning." Commonplace, indeed, it is—so very commonplace that it seems by many to be altogether worthless. Like a precious jewel amidst the dust beneath his feet, the thoughtless wanderer passes it unheeded; while he who is anxious to reach his destined point, looking well to his path, and glancing not only forward but downward, sees it glittering before him. There is no royal road to perfection in mechanism, any more than in other branches of science. The gems which genius is waiting to bestow are not on the surface, to be picked up at our loitering leisure; they lie deep in hidden mines, and to be won *must* be dug for. High mountains, if scaled at all, must be scaled step by step; or if with the wings of genius we make a bolder attempt, our upward flight is still the work of repeated strokes. Success is to be battled for, and if we go unarmed to the fight, we need not wonder at our being worsted; but in place of sitting down and crying over our misery, better far boldly to make another effort, under other and more consistent circumstances. Let not our experience and that of others be, as Coleridge so strikingly remarks, like the stern light of a ship, lighting only the part behind, but never sending a ray on to our forward path.

Not only, then, do we see the value of the lesson which the history of the men of science teaches us, as showing us what can be effected by careful study of what others have done before us, but the very steps in their progress which it records are but so many guides to us who follow in their footsteps, enabling us to avoid errors on the one hand, or to discover new combinations on the other. "The cursory perusal," says an able authority, "of documents containing accumulated knowledge, can hardly fail to suggest some idea novel to the reader; and as invention progresses step by step, and is the result of some improvement added to what was before known, the value of such information is too great to be duly estimated. Watt did not invent the steam engine, nor did Arkwright invent cotton-spinning machines; but it is well known that what they did was first to study the defects of existing machines, and then to add improvements, which not only produced to themselves ample fortunes and abiding fame, but to the country a degree of prosperity which has no parallel in history.

"In attempting mechanical improvements, the first step should be to learn what machines exist for the same purpose, and what are their defects; and so important is this subject, that it would be well if societies, constituted for specific purposes, would undertake to collect, classify, and promulgate all information

of value connected with the objects they profess to encourage."

An inventor, who, in any branch of mechanism, is anxious to bring out some new arrangement or combination to effect a specific purpose, but who is ignorant of what has been done before him in the same department, or whether anything has been done at all—a distinction of some importance, be it noted—will find, in the long run, that he has been performing a thankless task in only reproducing that which may have been effected long before; or, on the other hand, that if he has succeeded in bringing out something worthy, he might have done so at a less expenditure of time or money, as he has had to encounter difficulties which his predecessors had met before him, and, meeting, solved. An inventor in such a position is somewhat like a man going into what he deems a strange country, publishing as his own discoveries what a guide-book would have told him, and encountering dangers which a man of the route might have pointed out. In starting upon any voyage of discovery, it is well to inquire if we can get a pilot who can lead us in the right track, and tell us whether the lights which gleam upon us as we proceed are the *true* lights, or those which sparkle only to betray.

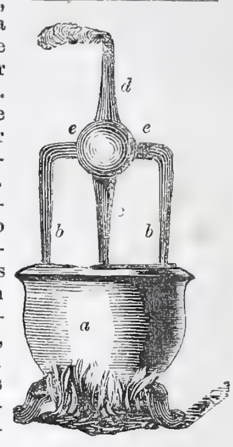
It is from considerations such as these, and most important they assuredly are, that we have deemed it right to precede our more practical details by historical notes. By means of these we hope to be enabled to present some valuable information of a truly practical kind. By them will be conveyed an idea of the successive steps in the progress of the invention, which have resulted in bringing it to its present state of comparative perfection.

With much that is so instructive to the young mechanic in the history of the steam-engine, there is also much that is interesting. Romance is not always confined to the page of the novelist; in the region of the actual, we find things as startingly striking and as fanciful as in that of the ideal. Thus, the first recorded point in the history of the wondrous steam mechanism, carries us back to a romantic region, and to a point nearly before history began its labours.

The truth of the fact seems generally received, that the ancient Egyptian priesthood were aware of the properties of steam, and used it for the purposes of their mystic faith. One of the contrivances for this purpose is thus described by Hero of Alexandria, 130 years before Christ:—"A steam-tight vessel or vase containing wine is placed within each image, the altar being made hollow and partially filled with water, bent tubes reaching from the space in the altar above the water to the space in the vases above the wine; and other tubes are taken from the vases, below the level of the wine, to the hands of the images. Matters being thus prepared, when you are about to sacrifice, you must pour into the tubes a few drops lest they should be injured by heat, and attend to every joint lest it leak; and so the heat of the fire, mingling with the water, will pass in an aerial state through these tubes to the vases, and, pressing on the wine, make it pass through the bent siphons, until, as it flows from the hands of the living creatures, they will appear to sacrifice as the altar continues to burn."

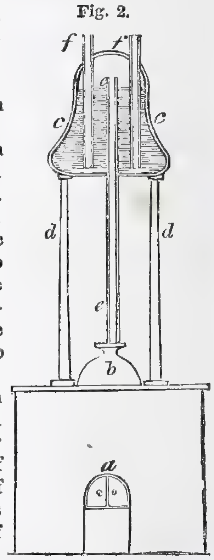
But the contrivance by which Hero is most generally known is the æolipile. A sketch of this is given in fig. 1. From the cover of a vase, *a*, containing water, heated by the fire underneath, two pipes, *b b*, are taken upwards, and bent in at right angles. The ends of these pipes are made conical, and work in corresponding apertures in the sides of the hollow globe, *e e*. From opposite sides of this globe, two tubes, *d c*, are led. At the extremities of these, but at opposite sides, apertures are made, one aperture to each tube. The steam or vapour passing out through these apertures, but in opposite directions, by their reaction cause the arms, and, in consequence, the globe to revolve rapidly, "as if it were animated from within by a living spirit." It is certainly suggestive to think that this ancient contrivance has been resuscitated in modern days, and brought out, under modifications doubtless, but still very simple modifications, as a rotatory engine. Passing by those contrivances which seem to have been more the closet speculations of the philosopher than the actual contrivances of the mechanic, we proceed to notice those which have a closer bearing upon the subject. We must notice two schemes, however, which were no doubt philosophical speculations only, but which contain the germ of two most important appendages of the modern steam engine. The first of these was a contrivance, published, in 1606, by Baptista Porta—who is known as the inventor of the camera obscura—for raising water from one level to another. Let *a*, fig. 2, represent a furnace which heats the water contained in the receptacle or vase, *b*. Another receptacle, *c*, containing the water to be raised to a higher level, is supported by two pillars, *d d*. A pipe, *f*, reaches nearly to the bottom of *c*, while another, *e*, communicating with the boiler, *b*, reaches to its top nearly. The steam raised in *b* passes up *e*, and, pressing on the surface of the water in the receptacle, *c*, forces it up the pipe, *f*. The sketch we have given is not taken from Porta's work, but is prepared merely to illustrate the description. In this contrivance we see the germ of the separate boiler. In fig. 3 we give a sketch illustrating an arrangement, proposed by Solomon De Caus, in a work published at Heidelberg in 1615. The pipe, *b*, reaches nearly to the bottom of the ball, *a*; to the interior of which the water was supplied by the pipe, *c*. On the fire being applied to the ball, the vapour generated pressed upon the surface of the water, forcing it up the pipe, *b*. In this arrangement we see the germ of the modern guage-cock.

Fig. 1.



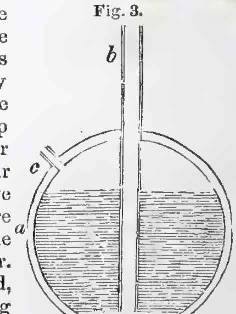
In fig. 4, we give a sketch of the steam wheel described by Giovanni Branca, in a work published by him in 1629, and believed, by some writers, to have been actually put in practice, for the purpose of working pestles in mortars, to mix up medicines. It is chiefly worth notice here, by reason of the very close resemblance a modern rotatory engine—Corde and Locke's, patented in 1841—bears to it, another instance of ancient invention, like Hero's æolipile, being resuscitated in modern days. From the sketch it will be perceived, that the steam issuing violently from the orifice in the mouth of the cauldron, impinges on the vanes of the horizontal wheel, to which it gives rapid motion, and through the agency of the shaft to the toothed gearing.

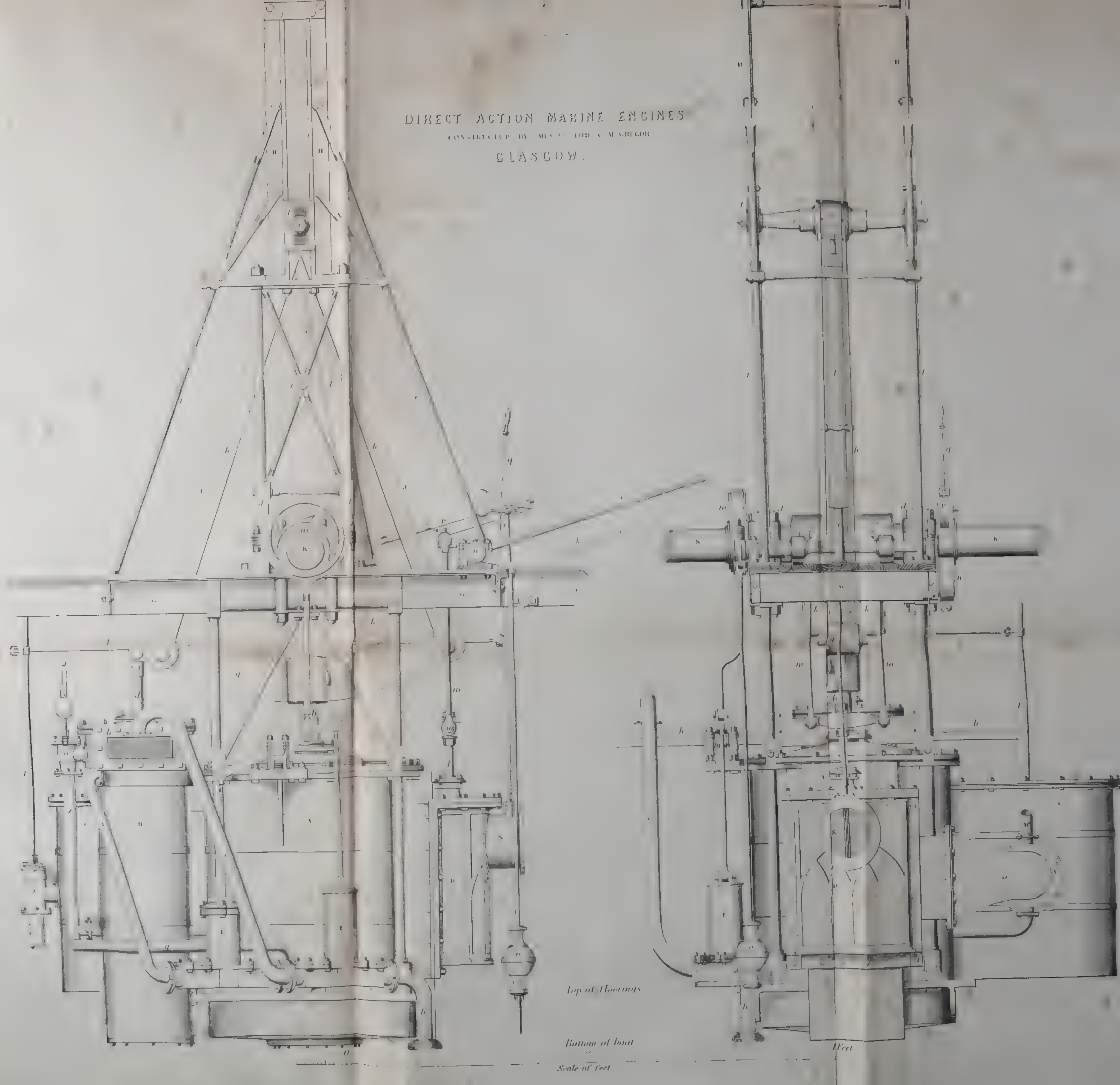
Fig. 2.



It is somewhat trite and commonplace to remark, that to the mineral wealth of her mines, England owes her proud position in the rank of nations; but it is not so often noticed, that one of the most potent powers—the steam-engine—which enables us to avail ourselves of their hidden treasures, probably owes its present perfection to the existence of this mineral wealth. Up to a certain period in the history of our social progress, the treasures of our mines—the coal and iron which have so ministered to our prosperity—were obtained in sufficient quantity by the power of horses or of manual labour. As the demand, however, increased, the difficulties attendant upon gaining these treasures increased also. The mines were made of larger extent, and reached a greater depth; but the power necessary to raise the materials the extra distance, and, more important, to relieve the interior of the mines from their

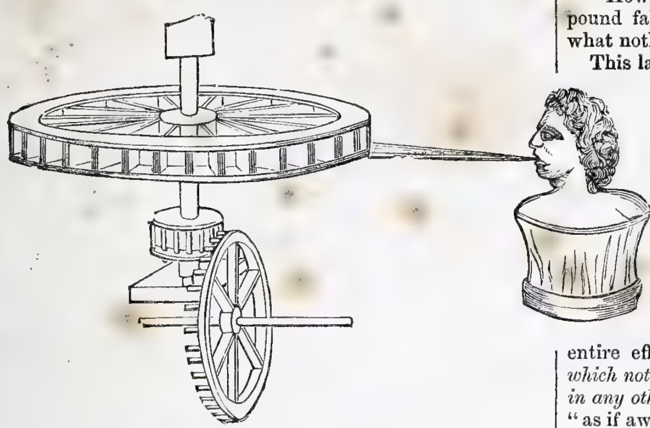
Fig. 3.




DIRECT ACTION MARINE ENGINES
CONSTRUCTED BY MESSRS TOD & MCGREGOR
GLASGOW.
Top of Floorings
Bottom of boat
Scale of Feet
Feet

rapidly accumulating waters, could not be increased in the same proportion. Hence arose the alternative which presented itself to the notice of our mine proprietors—either to stop working the mines when only partially exhausted, thus losing all the

Fig. 4.



labour and expense of the preliminary operations, or to find some power capable of doing the increased work. The Anglo-Saxon energy, then as now so potent, put the former alternative completely out of the question. Hence arose the repeated attempts to introduce the power of steam to raise the waters which threatened such losses. These attempts ultimately proved successful, and in themselves affording admirable incentives to further efforts, until ultimately the steam-engine took its place as a tried and valued power. Thus, in one way may our mines be said to have introduced the modern steam-engine, and in like manner may the steam-engine be said to have amply repaid the benefit, by the increased facilities it has placed at our disposal for obtaining their treasures.

We now approach an interesting period in the history of the steam-engine. We allude to that in which the celebrated Marquis of Worcester directed his attention to the power of steam, and the facilities it afforded for raising water in large quantities and at a cheap rate. Although the marquis, in his "Century of Inventions," published in 1663, gives—after the manner of the times when announcing any new discovery—but an exceedingly vague description of his invention, there is indisputable evidence that a machine on his principle was actually put to work in London, and successfully competed with a machine for a like purpose which was worked by two horses. In his 68th proposition in the "Century of Inventions," he thus describes his invention:—"An admirable and most forcible way to drive up water by fire, not drawing it or sucking it upward, for that must be, as one philosopher calls it, *infra sphœrum activitatis*, which is at such a distance; but this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it. Within twenty-four hours it burst, and made a great crack; so that, having found a way to make my vessels so that they are strengthed by the force within them, and the one to fill after the other, have seen the water to run like a constant fountain, forty feet high. One vessel of water, rarefied by fire, driveth up forty of cold water, and a man that attends the work has but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water; and so successively." This description seems obscure enough, but when taken in connection with the 98th and 100th proposition —a connection which a writer in the Glasgow Mechanics' Magazine (p. 316, vol. ii.) showed conclusively to exist—all deficiencies are made good. "An engine so contrived, that working the *primum mobile*, forward or backward, circularly or cornerwise, to and fro, straight, upright or downright, yet the pretended operation continueth and advanceth, none of the motions above mentioned widening, much less stopping, the other, but, unanimously and with harmony agreeing, they all augment and contribute strength unto the intended work or operation; and therefore I call this a *semi-omnipotent* engine, and do intend that a model thereof be buried with me."

"How to make one pound to raise an hundred as high as one pound falleth, and yet the hundred pounds descending doth what nothing less than one hundred pounds can effect."

This last proposition has been much cavilled at. "To raise a hundred pounds weight as high as one pound falleth, by the weight of that pound alone, carries absurdity in the face of it." Literally taken, this objection to the proposition is doubtless well founded; but that the marquis did not mean it to be taken literally, is proved by a document to which attention was first called by Mr. Stuart in his admirable work on the steam engine.* In this document, this proposition is *qualified* thus:—"I can make, says the marquis, one pound raise an hundred as high as the one pound falls, and the one pound being taken off, the hundred and twelve pounds shall again descend, performing the entire effect of one hundredweight—that is, I have *that force which nothing less than one hundred and twelve pounds can have in any other way*." "And he himself," remarks Mr. Stuart, "as if aware of its apparent difficulty, calls it *an incredible effect till seen*, but true as strange. It may be borne in remembrance that he is describing some of the effects of steam, and by these the riddle can easily be explained. The solution shows us that the noble inventor may have been describing *a high pressure steam-engine, whose piston, weighing a pound, and attached to one end of a lever, raises one hundred and twelve pounds placed at the other extremity*."

No diagram was published by the marquis illustrative of his invention. Numerous drawings, however, have appeared in various works of arrangements of mechanism, by which the effects as noticed by the marquis in his description could be obtained. We refrain from giving any of those—ingenious as many of them undoubtedly are—but leave it as a problem to our young readers.

We now proceed to investigate the results of what may be termed the *practical era* of the history of the steam-engine. The first work of this period is the well-known steam-engine of Savery. For this he obtained a patent in 1698, it being described "for raising water and occasioning motion to all sorts of mill-work, by the impellant force of fire." We have said that this was the first work of the practical era in the history of the invention. "The very mode in which the inventor ushered it into the world, and presented its claims to consideration, proved this. In place of clothing his description in the studied mysticism of words, which, up to this period, had been the endeavour of all those who had preceded Savery in describing inventions in connection with the subject, he, on the contrary, fully explained the principles of its action and the details of its arrangements, and, instead of giving exaggerated statements of its power and economy, he practically delivered the reasons why he believed it to be a cheaper method of raising water from mines than any other plan then in operation, and earnestly invited parties interested to inspect the machine in operation, and form their own opinion as to its working value." †

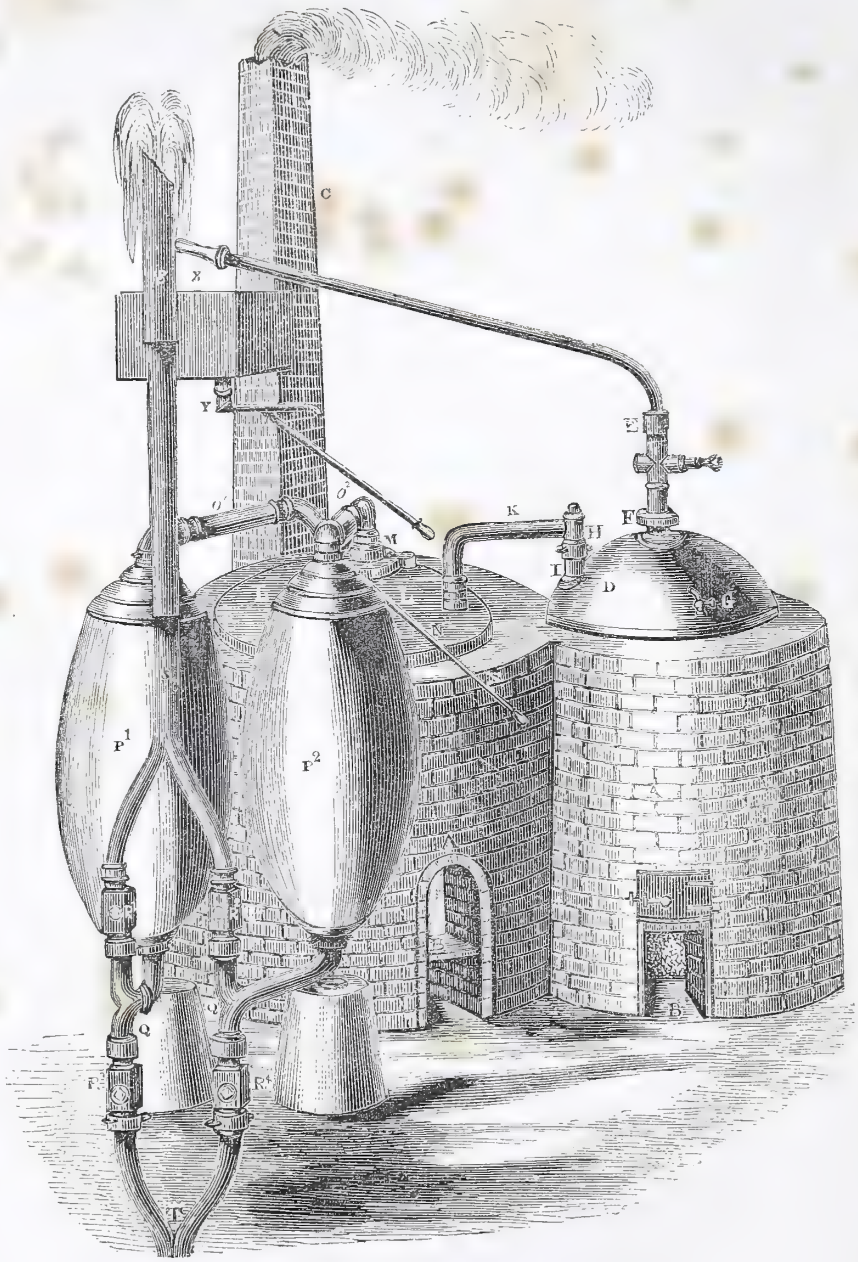
The following is the description published by Savery in his work entitled the "Miner's Friend:"—A A (fig. 5), the furnaces which contain the boilers; B 1, B 2, the two fireplaces; C, the funnel or chimney, which is common to both furnaces. In these two furnaces are placed two vessels of copper, which I call boilers, the one large, as L, the other small, as D; D, the small boiler contained in the furnace, which is heated by the fire at B 2; E, the pipe and cock to admit cold water into the small boiler to fill it; F, the screw that covers and confines the cock, E, to the top of the same boiler; G, a small gauge-cock

* Historical and Descriptive Anecdotes of the Steam-Engine and of their Inventors and Improvers. By Robert Stuart, Civil Engineer. Wightman and Cramp.

† "The Steam-Engine, its History and Mechanism, being Descriptions and Illustrations of the Stationary, Locomotive, and Marine Engine, for the use of Schools and Students." By Robert S. Burn. London: Ingram & Co. 3s.

at the top of a pipe, going within eight inches of the bottom of the small boiler; H, a larger pipe, which goes the same depth into the small boiler; I, a clack or valve at the top of the pipe, H (opening upwards); K, a pipe going from the box above the said clack or valve to the great boiler, and passing about an inch into it; L L, the great boiler contained in the other furnace, which is heated by the fire at B^1; M, the screw with the regulator, which is moved by the handle, Z, and opens or shuts the apertures at which the steam passes out of the great boiler into the steam-pipes, O, O; N, a small guage-cock at the top of

Fig. 5.



a pipe which goes half-way down into the great boiler; O^1, O^2, steam-pipes, one end of each screwed to the regulator, the other ends to the receivers, P, P, to convey the steam from the great boiler into those receivers; P^1, P^2, copper vessels, called receivers, which are to receive the water which is to be raised; Q, screw-joints, by which the branches of the water-pipes are connected with the lower parts of the receivers; R^1, R^2, R^3, and R^4, valves or clacks of brass in the water-pipes, two above the branches, Q, and two below them. They allow the water to pass upwards through the pipes, but prevent its descent. There are screw-plugs to take out on occasion to get at the valves, R; S, the forcing-pipe, which conveys the water upwards to its place of delivery, when it is forced out from the receivers by the impellant steam; T, the sucking-pipe, which conveys the water up from the bottom of the pit to fill the receivers by suction; there is a frame of wood, or a box, with holes round its bottom in the water, to enclose the lower end of the sucking-pipe, to keep away dirt and obstructions; X, a cistern with a

buoy-cock, coming from the force-pipe, so as it shall always be kept filled with cold water; Y, Y, a cock and pipe coming from the bottom of the said cistern, with a spout to let the cold water run down on the outside of either of the receivers, P, P; Z, the handle of the regulator, to move it by, either open or shut, so as to let the steam out of the great boiler into either of the receivers.

THE MANNER OF WORKING THE ENGINE.

"The first thing is to fix the two boilers of the engine in a good double furnace, so contrived that the flame of the fire may circulate round and encompass the boilers to the best advantage, as you do coppers for brewing. Before you make any fire, unscrew the two small gauge-pipes, and cocks, G and N, belonging to the two boilers, and at the holes fill the great boiler, L, two-thirds full of water, and the small boiler, D, quite full; then screw in the said pipes again as fast and tight as possible, and light the fire under the large boiler at B 1, to make the water therein boil, and the steam of it, being quite confined, must become wonderfully compressed, and therefore will, on the opening of a way for it to issue out (which is done by pushing the handle, Z, of the regulator as far as it will go from you), rush with a great force through the steam-pipe, O 1, into the receiver, P 1, driving out all the air before it, and forcing it up through the clack, R 1, into the force-pipe, as you will perceive by the noise and rattling of that clack; and when all the air is thus driven out, the receiver, P 1, will be very much heated by the steam. When you find it is thoroughly emptied and is grown very hot, as you may both see and feel, then pull the handle, Z, of the regulator towards you, by which means you will stop the steam-pipe, O 1, so that no more steam can come into the receiver, P 1, but you will open a way for it to pass through the other steam-pipe, O 2, and by that means fill the other receiver, P 2, with the hot steam, until that vessel has discharged its air through the clack, R 2, up the force-pipe, as the other vessel did before.

"While this is doing, let some cold water be poured on the first-mentioned receiver, P 1, from the spout, Y, by which means the steam in it, being cooled and condensed and contracted into very little room, a vacuum or emptiness is created, and consequently the steam pressing but very little (if at all) on the clack, R 3, at the bottom of the receiver, P 1, there is nothing there to counterbalance the pressure of the atmosphere on the surface of the water at the lower portion of the sucking-pipe, T, wherefore the water will be pressed up, and ascend into and fill the receiver, P 1, by what is commonly called suction: the water, as it rises, lifts up the clack or valve, R 3, which afterwards, falling down again and shutting close, hinders the descent of the water that way.

"The receiver, P 2, being by this time emptied of its air, push the handle of the regulator from you again, and the force of the steam coming from the great boiler will be again admitted through O 1, and will act upon the surface of the water contained in the receiver, P 1; which surface only being heated by the steam, it does not condense it, but the steam gravitates or presses with an elastic quality like air, and still increasing its elasticity or spring until it counterpoises, or rather exceeds, the weight of the column of water in the receiver and pipe, S, which it will then necessarily drive up through the passage, Q R 1, into the force-pipe, S. The steam takes up some time to recover its power, but it will at last discharge the water out at the top of the force-pipe, S, as it is represented in fig. 5, After the same manner, though alternately, the receiver, P 2, is filled with water by means of the suction, and then emptied by means of the impellant force of the steam, whereby a regular stream is kept continually running out at top of the force-pipe, S, and so the water is raised very easily from the bottom of the mine, &c., to the place where it is designed to be discharged. I should add, that after the engine begins to work, and the water is risen into and hath filled the force-pipe, S, then it also fills the little cistern, X, and by that means supplies the spout or pipe, Y Y, which I call the condensing pipe, and which by its handle can be turned sideways over either of the receivers, and is then open. By this spout cold water is conveyed down from the force-pipe to fall upon the outside of either of the receivers when thoroughly heated by the steam, in order to cool and condense the steam within, and make it suck (as it is usually called) the water out of the well up into that receiver.

"It is easy for any one that never saw the engine, after half an hour's experience, to keep a constant stream: for on the outside of the receiver you may see how the water goes as well as if the receiver were transparent; for as far as the steam continues within the receiver, so far is that vessel dry without, and so very hot as scarce to endure the least touch of the hand; but as far as the water is withinside of the said vessel, it will be cold and wet on the outside where any water has fallen on it, which cold and moisture vanish as fast as the steam in its descent takes place of the water. But if you force all the water out of the receiver, the steam, or a small part thereof, will go through the clack, R 1 or R 2, and will rattle that clack so as to give notice to move the handle of the regulator, and then the steam begins to force out the water from the other receiver, P, without the least alteration of the stream, only sometimes the stream will be rather stronger than before, if you pull the handle before any considerable quantity of steam be got up the clack, R: but it is much better to let none of that steam go off, for that is but losing so much strength, and it is easily prevented by pulling the regulator some little time before that receiver which is forcing is quite emptied.

"This being done, turn the cock or condensing pipe, Y, of the cistern, X, over the empty receiver, so that the cold water proceeding from X may run down through Y, which is never opened but when turned over one of the receivers, but when it stands between them is tight and stanch. This cold water falling on the outside of the receiver, by its coolness causes that steam, which had such great force just before, to condense and become an empty space, so that the receiver is immediately refilled by the external pressure of the atmosphere, or what is vulgarly called suction, whilst the other receiver is emptying by the impellant force of the steam; which being done, you push the handle of the regulator from you, and thus throw the force into the other receiver, pulling the condensing pipe over the receiver, P , causing the steam in that vessel to condense, so that it fills while the other empties; the labour of turning these two parts of the engine, viz., the regulator and condensing water-cock, and tending the fire, being no more than what a boy's strength can perform for a day together, and as easily learned as their driving of a horse in a tub gin. Yet, after all, I would have men employed in working of the engine, and those too the most apprehensive, supposing them more careful than boys. The difference of this charge is not to be mentioned, when we consider the vast profit which those who use this engine will reap by it.

"The ingenious reader will here probably object, that the steam being the cause of this motion and force, and that as steam is but water rarefied, the boiler, L, must in some certain time be emptied, so as the work of the engine must stop to replenish the boiler, or endanger the burning out or melting of the bottom of the boiler. To answer which, please to observe the use of the small boiler, D. It is supplied with water from the force-pipe by a small pipe and cock, E. When it is thought fit by the person tending the engine to replenish the great boiler (which requires about an hour and a half or two hours' time to the sinking one foot of water), he turns the cock, E, so that there can be no communication between the force-pipe, S, and the small boiler, D, and, putting in a little fire under the small boiler at B 2, the water will there grow presently hot, and when it boils, its own steam, which hath no vent out, will gain more strength than the steam in the great boiler. For the force of the great boiler being perpetually spending and going out, and the other confined and increasing, it is not long before the force in the small boiler exceeds that in the great one; so that the water in the small boiler being depressed by its own steam pressing on its surface, will force the water up the pipe, H, through K, into the great boiler, L, and so long will it run till the surface of the water in the small boiler, D, gets to be as low as the bottom of the pipe, H, and then the steam and water will run together, and by its noise and rattling of the clack, I, will give sufficient assurance to him that works

the engine, that the small boiler hath emptied and discharged itself into the greater one, L, and carried in as much water as is then necessary; after which, by turning the cock, E, again, you may let fresh cold water out of the force-pipe, S, into the lesser boiler, D, as before, and thus there will be a constant motion and a continual supply of the engine, without fear of decay or disorder. And inasmuch as, from the top of the small boiler, D, to the bottom of its pipe, H (which is within eight inches of the bottom of the boiler), there is contained about as much water as will replenish the great boiler, L, one foot, so you may be certain it is replenished one foot, of course.

"Also to know when the great boiler wants replenishing or not, you need only turn the gauge-cock, N, and if water come out there is no need to replenish it, but if steam only come, you may conclude there is want of water; and the like will the cock, G, do in reference to the small boiler, D, showing when it is necessary to supply that with fresh water from S, so that in working the engine there is very little skill or labour required; it is only to be injured by either a stupid or wilful neglect.

"And if a master is suspicious of the design of a servant to do mischief, it is easily discovered by those gauge-pipes; for if he come when the engine is at work, and find the surface of the water in the great boiler, L, below the bottom of the gauge-pipe, N, or the water in the small boiler, D, below the bottom of the gauge-pipe, G, such a servant deserves correction, though three hours after that, the working on would not damage or exhaust the boilers. In a word, the clacks being, in all water-works, always found the better the longer they are used, and all the moving parts of our engine being of like nature, the furnace being made of Stourbridge or Windsor brick or fire-stone, I do not see it possible for the engine to decay in many years, for the clacks, buckets, mitre-pipes, regulator, and cock are all brass, and the vessels made of the best hammered copper, of sufficient thickness to sustain the force of the working of the engine."

BUILDING ARTS.

CHAPTER III.

SPECIFICATION CONTINUED.

PLUMBER AND GLAZIER.

THE front wall and cornice gutter to be laid with four lbs. lead, two feet six inches average width. The back gutter, four lbs. lead (to the foot), width one foot nine inches. Centre gutter with four lbs. lead, two feet eight inches wide. Cross gutter with four lbs lead, one foot eight inches wide.

Flash the chimney gutters with four lbs. lead, eighteen inches wide. Cesspools with five lbs. lead. Bottoms and sides of cisterns with five lbs. lead, laying three inches under coping, and well soldered. Valleys to be flashed with four lbs. lead, one foot six inches wide. Flash and stop-flash chimneys with four lbs. lead, twelve inches wide.

Bow-window flats four lbs. lead, turning up three inches at walls, and flashed with four lbs. lead, six inches wide. Small roof at back to be flashed at brickwork with four lbs. lead, twelve inches wide. All laps to be six inches.

Well dress the lead over drips, cesspools, rolls, &c., in the most workmanlike manner. No nails will be allowed.

The water to be taken from back roof with a five-inch half round gutter, fixed with irons, &c., complete; and from the bow-windows with one-and-a-fourth-inch iron pipe, to have grids, &c., complete.

The cisterns are each to have two-and-a-half-inch plug and washer, two-and-a-half-inch trumpet-mouth overflow pipe, five feet long, three-inch iron waste pipe, with V heads and shoes. A three-quarter inch Chrime's stop-tap to be provided for each cistern, and a three-fourth inch service pipe; and Chrime's patent ball cock and ball to each kitchen boiler supply cistern.

Fix two patent chair water-closets with good siphon traps; four and a half inch soil pipe fitted into drain, and three-fourth inch service pipe.

The slopstone tap in each washhouse to have a five-eighth inch Chrime's patent tap, and three-quarter inch service lead pipe (six pounds to the yard) from the cistern above. The slopstones to have one-fourth inch waste pipe (nine lbs. to the yard), and bell trap complete.

Solder all pipes where required, and as directed. The plumber to provide all lead junction pipes required, and to do the whole of the plumbing in a satisfactory and perfect manner, and complete throughout.

Provide and fix earthenware basins, with plugs and washers, three-quarter inch service pipe, and one-half inch waste pipe, and five-eighths inch Chrime's taps to the pans and water-closets.

Lay five-eighth gas tubing under the floor boards to lights in the kitchen, drawing, dining-rooms, parlours, and lobbies, on the ground floor, as directed, and leave the whole perfect, and prepared for lights.

All the sashes in front of the house and the fan lights to the entrance doors to be glazed with the very best glass in one sheet, each well sprigged in, and otherwise properly secured, as may be described. All the rest of the windows, except where otherwise directed, to be glazed with the best seconds crown glass.

The front entrance door to be glazed with figured plate glass in one sheet.

The staircase windows to be glazed with figured sixteen ounce (to the foot) glass on white ground, and to have a coloured and figured margin on white ground, as approved pattern. The centre square to have a coloured bouquet of flowers about nine or ten inches diameter. The back entrance to door and dressing-room window to be glazed with common ground glass and light ornaments. The whole to be left clean and perfect at conclusion of the work.

SLATER.

The whole of the roof to be covered with best seconds (*here describe kind and quality of slate*), laid on fir laths, two-and-a-half by three-quarter inch, and two zinc nails to each slate. No imperfect slates will be allowed to be used.

The hips and ridges to have the very best patent ridge rolls, pointed with black mortar, and well secured to the timber; the bottom tiles in all cases to be screwed to the hips.

The lap one-half by three inches, and the seam six inches.

Thoroughly point the whole with good hair mortar. The bottom course of slates to be solid throughout. Point all flashing, gables, and chimneys. Cut all bevils required, and leave the whole perfect and clean at the conclusion of the work, repairing all broken slates.

PLASTERER.

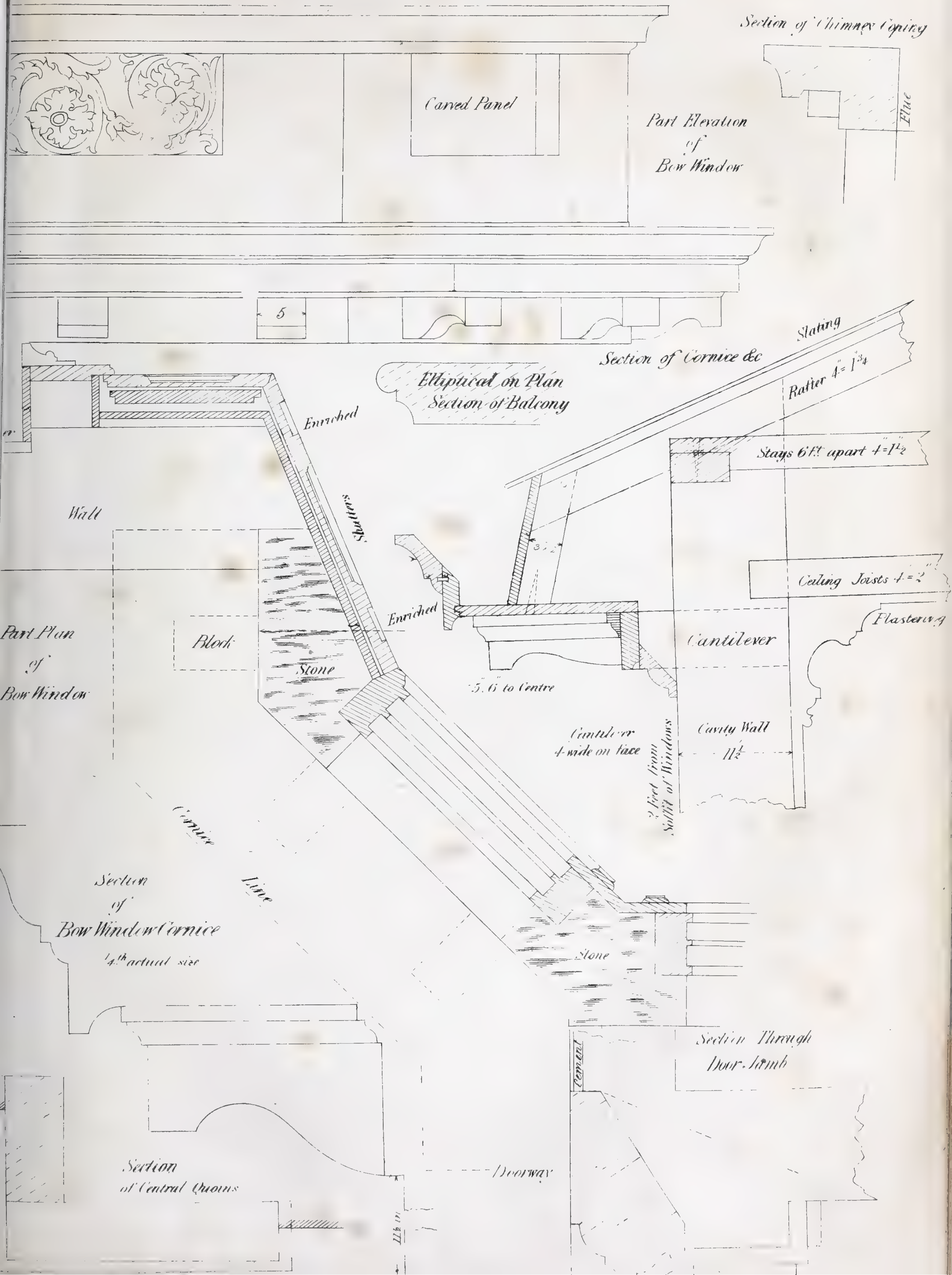
The whole of the walls and ceilings, including privies, to have two good coats of plastering, except the cellars, which are to have one coat only to the passage walls, and one to all the ceilings.

The porch to be cemented with Portland cement, and jointed to imitate stone. Run cornices as follows:—

To the dining and drawing-rooms two feet girt. Bow-windows twelve inches girt. Breakfast rooms and lobbies fifteen inches girt. Bed-rooms twelve inches girt. The lobby arches to have spandrels on each side, and small panel mold. Enriched moulding, four inches girt, to the dining and drawing-room cornices. The elliptical lobby arches to have an architrave on each side nine inches girt, and molded panels in soffit. All circular architraves and single molds required to front door, windows above staircase, windows, &c., to be turned in plaster in continuation of the straight wood molds. The ceiling over staircase landing to have panels three-fourth inch deep, as shown in section. The cellar lobby to have a cement skirting six inches deep. The lobbies each to have a centredrop in papier maché (*here state price*) of the value of before fixing.

The dining and drawing-rooms to have centre pieces of the value of thirty-five shillings each nett before fixed. Each drop to be properly prepared for gas lights.

The plasterer to bed and point all sash and door frames, to plaster at the back of all skirting solid, and to leave the whole


Section of Chimney Coping
Flue
Carved Panel
Part Elevation of Bow Window
5
Slating
Section of Cornice &c
Elliptical on Plan Section of Balcony
Rafter 4" = 1¾
Enriched
Stays 6 Ft. apart 4" = 1½
Wall
Shutters
Ceiling Joists 4" = 2"
Enriched
Plastering
Part Plan of Bow Window
Block
Stone
Cantilever
5.6" to Centre
Cantilever 4 wide on face
Cavity Wall 11½
2 Feet from Soffit of Windows
Cornice Line
Section of Bow Window Cornice
¼th actual size
Stone
Section Through Door Jamb
Cement
Section of Central Quoins
Doorway

of his work in a clean and perfect state at the completion of the works. The lime to be run one month before using.

PAINTER.

The whole of the wood and iron work throughout the two houses, stables, and privies, are to be painted three or four coats, as herein directed. The number of coats mentioned includes, in all cases, one coat of the best red or white lead paint. All the paint is to be of the very best quality, and free from all extraneous substances whatever. All varnishing is to be done with two coats of the best copal varnish. All knots are to be twice knotted and covered with tinfoil. All the wood and iron work, after having been primed, to be pumice-stoned and puttied prior to receiving the rest of the paint.

All the graining to be of the most superior quality, and to be of such shades as may be directed. All the plain paint to be of such tints as may be directed. The whole of the woodwork in each room to be painted and finished alike. The painter is to provide all tools, ladders, scaffolding, materials, and workmanship, and every other matter and thing required for completing the painter's work in the most superior and workmanlike manner; to repaint all work that may be damaged or soiled, and to leave the whole of the building complete throughout, at the completion of the work.

Paint the outside cornice and fascia boards two coats light drab; sand the same to represent stone, and draw fine light joints in paint where directed.

Paint all the window-sashes white, four coats inside and out. Drawing-rooms three coats, finished French white.

The contractor to state in his tender at what price he will gild mouldings per lineal foot, one inch wide for the rooms; to be measured when completed.

Dining-rooms to have three coats grained oak, and varnished in the most superior style.

Breakfast-room three coats, grained maple, and varnished.

Kitchen three coats, grained oak, and varnished.

Butlers'-pantries and sculleries three coats, party colours.

Pilasters and lobbies three coats, grained sienna marble, and varnished; caps to pilasters white-veined marble, and varnished; bases to pilasters light Aberdeen granite, and varnished.

Passages to both floors, landing, and lobbies, three coats painted oak, and varnished.

Paint the soffits and sides of lobby arches over pilasters four coats, grained sienna marble, fine jointed, and twice varnished.

Paint all the passage walls to both floors throughout, also the staircase and back passage walls four coats, plain and flatted.

All the bed-rooms to have three coats, and all the graining to be varnished. Bed-rooms over drawing-rooms finished maple; over dining-rooms finished satinwood; over kitchen finished birch; over breakfast-room finished maple.

The walls and wood skirting of bath to be painted four coats, finely jointed, to represent blocks of marble, and twice varnished.

The door to be painted and grained oak, and the window dressings marble. The servants' bed-rooms to be painted plain in party colours. Water-closets to be painted dark oak, and varnished. The sides and front of staircases and top of treads, except when stair-carpets are laid, to be painted three coats grained oak, and varnished. All the balusters to be painted three coats bronze, and varnished.

Front wall gates to be painted four coats bronze colour. All the ironwork to be well bronzed and varnished. All the wood and ironwork to the out-offices, coach-houses, stables, and cellars, to be painted three coats.

Twice whiten the whole of the ceilings. Twice colour the cement inside of porch to represent stone. Twice whitewash the whole of the cellar and other internal walls throughout the whole of the building not specified to be plastered.

Paint all the stone chimney-pieces throughout the two upper floors, except kitchen, Pardella marble, three coats, and varnished twice. Paint all the kitchen chimney-pieces, and the brickwork above the fire-place, on each side, three coats. Paint all the drain-spouts three coats.

SPECIFICATION FOR A SMALL SEMI-DETACHED HOUSE.

The following may be taken as a specimen of a form of specification used for houses of a small class, "semi-detached," £18 yearly rent, where the drawings are correctly drawn to scale, and consist of "cellar," "ground," and "chamber" plans, "front," "back," and "end" elevations, with "section," or "sections."

The whole of the work to be executed in the best possible manner, and the materials the best of their respective kinds.

All the walls to be of the full dimensions shown in drawings, and the foundations of the depth shown on section. The inside walls of cellar story to be 9 inches thick. The front sitting rooms and entrance hall only to be cellared.

Dig out the ground to the required depth for cellars, footings, &c. Remove the earth, and refill the space under flags of kitchen with the same, after the erection of building, well ramming the earth against walls, &c.

BRICKWORK.

The principal front and two ends to be set with good seconds brick, sound and hard burnt; neatly jointed, and dressed off with putty, as also the chimneys.

The remainder of outside walls to be set with the best hard-burnt common bricks, neatly rubbed and jointed. The cellar walls inside to be pointed for whitewashing. All other walls left rough for plastering.

The flues to be 14 inches by 9inches, well pargetted from top to bottom.

The bricklayer to fix the cellar steps, cills, heads, flagstones, &c.; as also the boilers and stepstones.

Lay the bottom of ashpits with brick on edge paving, well grounded with mortar. Divide the two closets under stairs with brick on edge zigzag.

STONEWORK.

Provide heads and cills of the respective sizes shown on plans, polished. The cills of bay windows to be ten by six inches, polished; the mullions to be eight by seven inches, chamfered.

The fascia over mullions to be nine by six inches, plain; the cap nine by six inches, polished and moulded.

Provide two heads twelve by four-and-a-half inches, and two cills ten by twelve-and-a-half inches, to cellar windows. The chimneys to have coping seven by three inches, with blocking six by two-and-a-half inches, well clamped together. Cover the walls of privy and ashpit with thirteen by two-and-a-half coping, tooled on the edge and cramped.

The kitchen, sculleries, and back passages, to be laid with good self-faced flags, square jointed, and bedded in sand. The cellars and privies to be laid with the same flags.

Provide steps to cellars three feet six inches by twelve by two-and-a-half inches, tooled on the edge.

Provide and fix two steps and stone risers to each back-door three inches thick, tooled.

Fix to front entrance of each house one large step four feet six inches by two feet; as also one door-step three inches thick, with risers polished. Line the areas of cellar windows with two inch flag.

Provide two step-stones five feet by one foot eight inches, as also two covers to boilers two inches thick, polished. Provide urine stones to privies and lodge-stones to back-doors fourteen inches by nine by six inches.

Provide and fix chimney-pieces of the following value to the several rooms:—Kitchen 20s. each, four best bed-rooms 20s. each, two other bed-rooms 12s. each, two sitting-rooms 25s. each, two dining-rooms, 50s. each, the latter of marble; as also polished front and back hearths, not less than two inches thick, and six inches longer than the respective openings.

CARPENTERS AND JOINERS' WORK.

The whole of the bearing timber to be of the best Quebec pine, clear of sap and large dead knots. All bearing timber, as joist and studding, to be not more than sixteen inches apart from centre to centre. All the prepared work to be dry and

well seasoned, and of the best American pine, except where specified to the contrary. The floors of sitting-rooms and entrance-hall to have joists seven by three inches, laid with inch narrow spruce boards, dry and seasoned, well cleaned off, and the holes puttied.

The dining-room floors to have joists four-and-a-half by three inches, laid on sleeper walls covered with four-and-a-half by three-inch bond timber, the boards to be laid with narrow inch spruce, dry and seasoned, well cleaned off, and the holes puttied.

The chamber floors to have joists seven by two-and-three-fourth inches, laid as the above.

The flat on top of roof to have joist five by three inches, framed into a curb of the same, covered with inch spruce boards, with proper fall to edges.

The rafters to be three by two inches, purlins seven by three inches, hip and valley rafters ten by two inches, ridge and hip roll two feet by two inches.

Fix a fascia with bold moulding, as shown in section, lined underneath with a three-fourth inch board, dressed, &c. The gutters to be laid with proper fall to spouts.

The flat over bay-window to have joists four-and-a-half by three inches, laid with inch boards.

Provide beams to carry wall above bay-window, as also wall over scullery fourteen by nine inches.

Provide lintels three inches thick, and nogs to all door and window openings.

The floors to have each one row of bridging, seven by one-and-a-half inches.

The windows to be of the size shown, the frames to be four by three inches, rebated and grooved for shuts, two inches thick, moulded, and the joints to be tongued and rebated.

Cills to frames and shuts to be of red deal, and double sunk.

The cellar windows to be four feet by three feet; the whole to be hung in the lower compartments with two-and-a-half inch wrought-iron butt hinges, and fastened with brass casement fasteners.

Provide one-and-a-fourth framed and moulded box shutters to dining-room windows and sitting-room, with architraves, framed soffits, one inch back linings and grounds complete; to be hung with two-and-a-half inch wrought butts, and one-and-a-half back cap hinges, fastened with shutter-bars and the necessary bolts.

The front doors to be two inches thick, framed for glass in the upper part, to jambs five-and-a-half by three inches red deal, beaded and rebated, with eight-inch draw-back lock, four-inch wrought bolts, and one eight-inch barrel bolt to each. The outside to have neat cornice and pilasters. To be fitted inside with box shutters to close the glass panels, and framed elbows to match, hung as before, with architraves, grounds, and linings complete.

Provide and fix two-inch doors to each entrance lobby, moulded on both sides to rebated casings, not less than one and three-fourth inch thick, hung with four-inch butts, and best six-inch mortice locks to each. All other doors in ground and chamber stories to be (except cellars under stairs) one-and-a-half inch thick, moulded, and hung to casings as before; three-inch butt hinges, and six-inch rim lock to each.

The closet doors to be one-and-one-eighth inch thick, with casings, two-and-a-half inch hinges, and four-inch closet locks, fitted inside with hooks, rails, and shelving.

The cellar doors to be three-fourth inch, ledged to cheeks four by three inches, with T hinges and thumb latches. The back door to be one-and-a-half inch, framed bead, and flush to joints five-and-a-half by three inches, hung with three inch butts and rim locks, and eight-inch barrel bolts; each to have a fan-light over, with rim-post, &c.

Fix splayed casings to all reveals of windows. The splays of chamber windows to run to floor. Plain casing to back doors, and, where required, architraves five inches wide to doors in entrance hall, sitting and dining-room. All other doors and windows to have single moulds three by one inch thick.

The lobby to have moulded base and plinth ten inches deep, with grounds two by three-fourth inch. The dining-room and sitting-room to have double skirting twelve inches deep, grounded as before. All other rooms, passages, &c., to have torus skirting, seven inches deep and one inch thick. The closets to have skirting five by three-fourth inches, beaded. Fix one-inch angle beads to all angles for plastering. Fix feet of shelving on proper nogs in each house.

The studding across chambers to be three by three inches, well braced.

The stairs to be three feet wide, notch-boards moulded, one and one-fourth inch thick. Treads one and one-fourth inches, rounded on the edge, with cove moulded underneath. Risers one inch thick. To be finished at the top with mahogany rail and turned newel, balusters, &c., complete.

Provide and fix one cupboard in each house, with one and one-fourth inch framed and moulded fronts in two heights, fitted with five shelves, inch thick, and three hook rails in each; locks, hinges, &c., complete.

The privies to have inch seats, and covers on proper bearers, skirted round, &c. The doors to be ledged three-fourth inch thick to cheeks three by three inches, hung with T hinges, latches, &c.

PLASTERER.

The entrance, dining-room, and sitting-room to have a neat sixteen-inch girth. The ceiling of above to have three coats, well smoothed off. All other ceilings and walls in ground and chamber floors to have two good coats of hair mortar, as also the privies.

Fix two ornamental arches with trusses to opening of stairs.

The ceiling of cellars to have one good coat of hair mortar, floated level, and left smooth.

PAINTER.

Paint the whole of the wood and iron work usually painted, three good coats of oil paint, well knotted and stopped. Whitewash the cellars and privies, two coats.

GLAZIER.

The cellar windows to have crown glass. All other windows to be glazed with good sheet glass, 21 ounces to the square foot, well bedded in putty, and left perfectly clean. Fix two lead slopstone pipes to drains, with trap complete.

BOTANY.

CHAPTER X.

ORGANS OF REPRODUCTION, CONCLUDED—THE PISTIL.

That two cells, endowed with different properties, are brought into contact in order to the production of vegetable fruit and seed, has long been manifest to botanists, throughout every kind of flower-bearing plants. In the flowers called hermaphrodite, where the sexes are associated together, the removal of the stamens, or male organs, has the effect of frustrating the formation of fruit and seed; and in all double flowers where the stamens are metamorphosed into petals, which is equivalent to their cutting away, the same result occurs. Where the male and female organs are separated in the same plant, as in Cucumber, the removal of the stamen-bearing flowers causes barrenness to the pistil-bearing flowers. The same thing again happens when the pistils are placed on one plant and the stamens on another, as in Date Palm. This fact was remarkably exemplified during the war of the Mussulmans with the French in the year 1800, in Lower Egypt. The natives being then unable to repair to the woods, after their usual manner, to procure wild stamen-bearing flowers for presenting to the pistil-bearing trees, a total failure of the Date crop that year was the consequence.

The pistil is the female organ on which the pollen is shed, and is the innermost whorl in the parts of fructification. It is the collective name of the part or parts which compose it, whether one or more. As the leaves of the calyx and corolla are respectively termed sepals and petals, so those of the pistil are *carpels* (καρπός, fruit). A similarity in texture, venation, and vital organism, establishes their analogy to leaves.

Parts of Fructification.

Their occasional conversion into leaves is to be met with in Broad-leaved Everlasting Pea; and in Double-flowering Cherry, where no fruit is produced, a flat or folded leaf is the form in which they appear. The carpel is, in fact, a transformed leaf, with its edges united, and generating vegetable eggs at the inside of the suture, while its midrib is made to terminate in a porous disc.

The pistil may consist of a single carpel, then called *simple*, as in Pea; but when it is compounded of several carpels, each either stands distinct, as in Pæony, or the whole are more or less combined, as in Tulip-tree. The carpels are united, it may be, either by the lower portion, as in Rue; the middle, as in Mallow; or the top, as in Swallow-wort. When the union is complete, the grooves between the carpels usually indicate their number.

If arranged on a flat receptacle, the carpels may be considered of equal length, as in Hardy Annual Crassula; but in many species their position is conical, convex, or concave, as in Raspberry, Strawberry, and Rose.

We will treat of the structure of the pistil; and then explain, successively, the theory of its fecundation, and its development after flowering into fruit and seed.

I. The rounded top of the pistil is called the stigma; the stalk, if any, upon which it is raised, is the style; and the swollen part at the bottom, containing the cells which become seeds, is the ovary. See Plate X., figs. 2, 3, 4; also 6 and 7, which exhibit the organs of Tree Primrose. Fig. 6: *a*, cleft stigma; *b*, style; *c*, germen. Fig. 7: *a*, pistil; *b*, stamina; *c*, petals; *d*, upper part of calyx; *e*, lower part of do.; *f*, germen. The stigma and ovary are always present; the middle part is not invariably essential; and, when absent, the stigma is sessile. Plate X., fig. 5. Let us pursue these consecutive structures from the top downwards.

1. The *stigma* is a loose and spongy expansion of the cellular tissue of the style, dotted over with minute projections or little swellings, termed papillæ. As the papillæ become more minute and at last evanescent in the ovary, the stigma is an absorbent device, and secretes a viscous fluid, in some cases acid, but more generally saccharine, for combining with the pollen at the period of fertilization. The process is smooth in Water Lily, but the papillæ are developed into hairs in Small Nettle. The stigma assumes in Grasses the form of a hairy tuft or brush.

In point of position, it is terminal to the style in Spurge Laurel; lateral in Carnation; and on both sides in Eupatory. In Swallow-wort it is united with the anthers into a solid mass, and exhibits no distinguishable style. Its situation in the Orchids is even more peculiar; the place it occupies in that tribe is called *gynizus* (γυνὴ, pistil, and ἵζω, to sit), being on the column formed by junction of the styles and filaments.

Divisions sometimes take place in stigmas, as in Monkey-flower, which is furnished with two contractile lips. In Composites they are small, and are called bifid, &c., as in Polemonium. When of a larger size, as in Poppy, they are called lobed. If of a flattened shape, as in Bignonia, they are lamellar.

Among the forms presented by the stigma may be mentioned the ovoid, as in Fuchsia; the concave, as in Side-Saddle-flower; and globular, as in Common Marvel of Peru. The stigma of Rhubarb is composed of three flat orbicular discs. In Poppy, just alluded to, it is radiating. Plate X., fig. 1.

2. The *style* is formed by an extension of the midrib of the carpel, with the other tissues enveloped in it, and is hence both of a cellular and vascular nature. It is traversed lengthwise by a canal, the inner surface of which is coated with a row of projecting cells called the *conducting tissue*, on account of its function in transmitting the pollen downwards. Its general position is on the summit of the ovary, and is then called *apicilar* (*apex*, top). But as the organic apex of the ovary is not always the apparent apex, the style will be found in Cocoa-plum to be *basilar*, or arising from the base. When prolonged continuously from the torus, as in Ochna, it is called *gynobase* (γυνὴ, pistil, and βάσις, base).

The styles of a pistil may be either separate or united. When single, as in Angular-leaved Physic Nut, it may be bifurcate or forked; and where two or more styles exist, each may allow of a similar division. A union carried slightly above the apex of the ovary, is bipartite, tripartite, &c.; if extended higher up, bifid, trifid, &c., according to the clefts formed; and when the union is complete, the style is then simple.

In form, the style is usually cylindrical or triangular. It is petaloid in Indian Reed. In Vetch and Throatwort it is furnished with hairs in various forms, which assist in collecting and scattering the pollen. The provision for this application in Coventry Bells, and other species of Campanula, is highly admirable. From being at first shorter than the stamens, they ultimately attain to twice their length, and in their progress brush the anther cases, thus raising the pollen within reach of the instrument which has to apply it. Nor does the adaptation cease here; for the stigmatic surface also, at first erect, becomes changed to a revolute posture, so as to stoop to contact with the hairs, and imbibe the dust with which they are fraught.

3. The lower portion of the carpel is the *ovary*, or organ which secretes eggs; and is usually called *germen* by the Linnæan school of botanists. Its cellular texture, ramified with spiral and other vascular bundles, is consolidated into a spherical or curved form, and encased in an epidermis which is either smooth or hairy. The limb of the carpel leaf is either closely or more loosely united; and the fold is marked by dorsal or ventral sutures, expressed by projected or grooved lines along the surface. It is either free, or fixed to the calyx or other surrounding parts; and is said to be superior or inferior, according to the complete (Melon) or partial (Saxifrage) adherence of the one with the other. When continuous carpels are united to form a septum or fence, the boundary line is called *dissepiment* (*dissepio*, to separate), from being formed by the union of two membranes or laminæ. When such dissepiments are carried into the centre of the ovary, they divide it into loculaments (*loculus*, a box); and according to their number, the ovary is called unilocular, bilocular, &c. Apartments, however, are sometimes formed in ovaries, called *phragmata* (φράγμα, an enclosure), different from dissepiments, which derive their character from the edges of contiguous carpels. Such enclosures are ranged in the form of horizontal shelves in Cassia Stick or Pudding-pipe-tree; in other cases they are vertical, as in Thorn Apple.

On some interior part of the ovary thus provided, a number of soft projections are to be found, called placentas, from which bodies of female or unimpregnated semen, termed ovules, are arranged to branch or bud off, and form the future seeds when fertilized by pollen. In the Pine tribe there is no ovarian covering, consequently their ovules are naked; but in Mignonette, from being slightly exposed by a particular fold of the carpel, they are what is called semi-nude. The placenta and its ovules are the parts now awaiting description.

(1.) The *placenta* subsists under various arrangements; it occupies a flattish space in Clove-tree, but is confined to a single point in Nettles. In Pansy, it is merely a thickened portion of the parietes, or outer wall, and is then called marginal; its situation in the centre, thence termed central, is to be met with in Hirsute Mouse-ear. The whole inner surface of the ovary, or of each loculament into which it may be formed, is the seat of a placenta in Water Lily and Flowering Rush; and it is exhibited in lines along the dorsal suture or within the margin, in Water-Shields and Brown Rape. With such peculiarities, the most eminent physiologists are not agreed on its normal place.

(2.) Attached, as we have said, to the placenta, is the body called *ovule*—a sort of seed-bud, which enlarges itself from a small cellular mass into an ovoid form. It stands on a base called *chalaza*, which is a denser membrane, sometimes tinted, compounded of cells and vessels, and traversed by a tissue from the placenta. The ovule is either sessile, from being bedded in the placenta, or is attached, as in Armenian Seedwort, to a petiole arising from it, called *funiculus* (*funis*, rope), the base of which is the *hilum*, representing its true organic lower extremity. A vascular cord sometimes, as in Dandelion, passes through the funiculus, forming a ridge upon it called the *raphe* (ῥαφή, a seam), which becomes a connecting medium between the chalaza and placenta.

The relations of the ovule to its contiguous parts determine

its position. When its axis corresponds to a straight line drawn from bottom to top, it is called *erect* or orthotropal (ορθος, straight, and τρόπος, mode), as in Buckwheat order. The ovule is said to be *ascending* orthotropal, when inserted a little above the base, as in Pellitory. But curvation takes place in Cabbage and other crucifers; when the curve is formed on both sides of the axis equally, as in Canadian Moonseed, the ovule is called *camptropal* (καμπτὸς, inflected); and when unequally, as in Stock, *campylotropal*, (καμπτύλος, bent). When the apex is directed downwards, as in common Celandine, it is *anatropous* (ἀνατρέπω, to subvert), but this position admits of two minor distinctions; when the placenta is at the summit of the ovary, with the apex inverted, it is *pendulous* anatropous, as in Mare's tail; or, when only near to the summit, it is *suspended*, as in Mezereon. In addition to these forms, the ovule may be drawn into a disc, called *lecotropal* (λεκος, a bowl, and τροπος); or when the hilum, or point of attachment, lies in the middle of the ovule, it is *peritropal* (περι, around), or horizontal.

Considered in reference to each other in the ovary, the ovules are called *definite*, when sufficiently uniform to be counted; but when their position exhibits such a variety as not easily to admit of enumeration, they are *indefinite*. In the case of two or more being occupants of one cell, they may be either collateral—that is, placed mutually sidewise; or the apex of the one may point upwards and the other downwards, as in Horse Chestnut; or they may all follow the same direction. In leguminous plants they lie in rows.

The ovule itself consists of the nucleus, integuments, and embryo sac.

a. In its early stage, a cellular projection is formed on the side; and it is to this speck, surmounted by another girdle of cells, the name *nucleus* is given, in a more compound sense than when applied to single cells. In this succulent excentre, we arrive at the arcanum of vegetable nature—the workshop, in which a perfect species begins to reproduce its own miniature image, and to clothe it with new-born lineaments.

b. The nucleus is exposed in Small Henbit, Swallow-wort, &c.; but in most plants, one (Bell-flower) or more *integuments* or coverings, expanding in a ring-form from the base towards the top of the ovule, where they are arrested, make their appearance during the changes and fugacious developments which supervene upon it. The exterior integument is called *primine*, and the inner is the *secundine*, after their real order of formation. The line of opening by which one integument shelves on another is called the *foramen*; and when that mark is retained in the seed, *micropyle* (μικρὸς, small, and πύλη, gate) is the strict name bestowed.

c. In the course of its development, the interior of the nucleus is observed to have acquired a distinct cavity. This is the sac of the embryo. In Misleto, Pines, Cycads, and Onion, there are several sacs; and these tribes, on that account, are favourite subjects for examination. The sac is extended beyond the apex of the nucleus in Common Chickweed, and White or Yellow Sandalwood; and in Speedwell, its neck becomes diffused in filamentous appendages.

The accounts which have been given of the single, or virgin state of the sac, are subject to some variation, arising chiefly, we should suppose, from confounding the stages of development which succeed fecundation with those that precede it; but the best supported views, from observation and analogy, concur in representing the interior of the cavity, when fully developed, as furnished with a lining, utricle, and suspensor.

The *lining* is one of great delicacy, called *epithelium* (επι, upon, and θῆλυς, tender). It secretes the amnios, or mucilaginous fluid, for forming and nourishing the embryo.

The sac eventually manifests a spherical vesicle within it, which is the *utricle*. All the other parts are accessary to this vital centre, which is destined to be acted on by the spermatic union of the pollen. The utricle, when impregnated, is converted into an embryo.

The utricle is suspended to the summit of the sac, or apex of the nucleus, by a thread-like process, called *suspensor*. The rise of this body has been variously assigned to the pollen tube (Schleiden), to the sac (Amici), and to the germinal vesicle (Mohl.) In length, it does not always bear a proportion to the object which it attaches. Griffith refers to a seed of Gnetum being one inch long, while its suspensor varied from $3\frac{1}{2}$ to 5 inches. A case to the same purpose is mentioned by Dickie, in Common Whitlow Grass, where the suspensor exceeded three times the size of an embryo, of $\frac{1}{440}$ of an inch in length.

With these wonderful combinations, the ovule contains the rudiments of a future vegetable, transformed from its parts by slow but successive expansions. Every fibre in it contributes its share towards the production of that specific form of development which appertains to a perfect plant of its kind. The outlines inherent to the cell, in short, are merely filled up, from a first sketch, by the several processes which form its after physiology.

II. We have now, therefore, to look to the change passing on the pistil, when the pollen reaches it.

The application of plant-juice to a particle of pollen occasions a great change of the form assumed by it in a dry state. The effect may be easily shown, in the way of experiment, by immersing a grain in a vessel of water. A continued exposure to that element is observed to be attended, in general, with a rupture of the extine, in the first instance; and the intine, though resisting more from its greater distensibility, ultimately gives way, either through the first rupture, or the folds or pores of the outer surface. The immediate consequence is the escape of the vegetating contents of the cells, called fovilla; and this result indicates the plan after which fertilization, or fecundation, commences.

When the pollen grain is transferred to the absorbent surface of the stigma, the fluid which the latter secretes is applied, under regulation, on the lower side only. A growing distention, therefore, takes place in that direction—that is, downwards—so as to form a prolongation, called the *pollen tube.* The formation of these tubular insertions, in Orchids and Swallow-worts, was demonstrated by Brown above twenty years ago,* and that action of the pollen has been amply confirmed by succeeding inquirers. The tube appears at first like a minute knob, emanating from the pores of the grain, and gradually descends, through the style, in the direction of the ovule. Decaisne † has shown the curious fact, that in Misleto, the ovule does not become ostensible till three months after the pollen has been applied. Klotszch states that the tubes formed in Common Annual Lavatera and Tobacco may be seen extending to the sac on the second or third day; and it has been ascertained, that only a few hours are often sufficient for their production in Toad-flax, Sage, Tree-primrose, &c. In respect of size, they have been found diminishing below the $\frac{1}{3000}$ of an inch in diameter.

Though little division of opinion now exists thus far in the business of generation, it is matter of dispute as to the extent to which the tubes descend into the pistil before bursting, and letting loose their fovilla. The question, therefore, has been agitated, whether the tube penetrating to the ovule involves it in a sort of reflection, so as, by itself, to constitute the embryo in a cover? But in ovaries, where no passage of a style intervenes, such as Misleto, Pines, and Cycads, in which the ovule is spread open or naked, the fovilla is discharged on the stigma, or otherwise directly absorbed. Another great question, therefore, has been started in respect to the share of the relative organs; in other words, whether the tubes only influence a portion of matter inherent in the sack? The special difficulties attending the study of this genesis arise from the nicety in which it is shrouded, the high optical powers required in the investigation, the sources of fallacy open from the condition of the subjects examined, the absence of a common unity of operation, and the consequent hazard of generalizing from specific cases.

Schleiden,‡ from his elaborate researches on the physiology of plants, stands at the head of a party. He maintains that the pollen tube descends down the style, through the intercellular passages of the nucleus into the sac; that, in certain instances, it makes an entrance into the sac, but, in the majority, only remains on the outside, pushing or pressing it, and

* Trans. Linn. Soc., 1833. † Mémoire sur le Développement du Gui.
‡ Nova Acta Academ. Cæsar., Leopold-Carol.

in that manner forms a bag, consisting of the indented sac and its membrane, on the one hand, and the membrane of the pollen tube itself, on the other. A free portion of the tube, thus immersed in the flexible exterior of the sac, may be formed, according to him, into a suspensor; while the presence of more than one tube determines a plurality of embryos.

Professor Wydler, of Berne, has concurred in these views, with the exception, that he did not observe the double foldings which Schleiden assumes as the first stage of the embryo. Amici* says, he examined the parts of Pumpkin Gourd, together with Meadow and Early-spotted Orchis, in all which he traced the tube into the nucleus. He also noticed, distinct from the pollen tubes, a number of fluid-celled filaments, elongating upwards through the interior of the placenta; and Dickie † has corroborated such cellular passages passing upwards from the ovule, in Common Eyebright, in the Rush, called Narthecium ossifragum, and in the Figwort, known as Odontites. In a recent volume (xviii., p. 71) of the Linn. Transactions, Mr. Griffith has investigated the ovule in the two orders of Sandalworts, Santalum and Osyris; and in the two orders of the Misleto family, Loranthus and Viscum. In these he found the pollen tube passing longitudinally through the sac; and, in some cases, developing at its end what he considered embryotic cells. Wilson ‡ has inferred, from Round-leaved Bell-flower, that the pollen tube reaches into the foramen of the ovule. Tulsane professes to have examined the three species of Speedwell, Veronica hederifolia, triphyllos and præcox, with similar results; and, under slight modifications, the opinion has been advocated by Meyen § and Gelesnow.

But the doctrine of Schleiden, while it has stimulated the inquiry, has also provoked the opposition of other observers, who object to the general application of his conclusions. The investigation has been pursued in France by MM. Mirbel and Spach, who were led to believe that the tube, after proceeding a certain way down the style, ruptures, to discharge its fovilla in the conducting tissue, which conveys it to the ovule. From an examination of various plants, comprising Grasses, Yew, and other Pines, they found the interior of the sac occupied with a native substance, to which they gave the name of primordial or primary utricle. The ovule of Common Maize, in particular, was subjected by them to a scrutiny, with the following results:—1. With no true sac in this plant, they yet found an incipient utricle, without an act of impregnation having been effected. 2. The embryo of the plant contained only one, and not two, of the membranes described by Schleiden. Dr. Giraud,‖ at home, took up the same inquiry in Great Indian Cress, in which he declares that "the pollen tube is never brought into contact with the embryo sac." He traced the sac, and its included vesicle, thus:—The contact of the fovilla with the sac took place on the outer surface of that membrane; the utricle, with its suspensor, became lengthened through the apex of the sac, and even protruded through the nucleus and foramen, so as to communicate with the conducting tissue; and at the inferior extremity of the utricle, the dynamic influence of the fovilla determined a spherical point, which supplied the first clue of the embryo.

The subject has been impartially gone into by Mohl, Nageli, Karl Müller, Brongniart, Hofmeister, and others. Upon the whole, the evidence preponderates in favour of a germinal vesicle being peculiar to the pistil, of the contact of the pollen tubes with the sac, and of the connection of the granular fovilla of the one with the mucilaginous fluid of the other, giving rise to a common cellular body, whose function is to reproduce, from its interior, a succession of cells like itself.

Our space will not allow of entering on the consideration of fruit and seed, which only represent the impregnated pistil as arrived at maturity. This is the point at which Nature makes ready to renew the progress of growth, and to complete the circle she began at the root, under the law of Him who is the Beginning and the End.

* Annales des Sciences Naturelles, 3d Ser., tome vii.

† Annals of Natural History, 1848.

‡ London Journal of Botany, vol. ii. § Taylor's Scien. Mem., vol. iii.

‖ Trans. Linn. Soc., vol. xix.

THE SCIENCE OF PHRENOLOGY.

ORDER I.—FEELINGS.

GENUS II.—SENTIMENT.—(*Continued.*)

CHAPTER XII.

20. WIT.—The organ of Wit is situated on the upper and outer part of the forehead, on the side of Causality, and immediately before that of Ideality. Of this faculty Dr. Spurzheim remarks, that it diffuses over the mind a disposition to view objects and events in a ludicrous light, in the same way as Ideality tends to exalt all its functions. It may be combined with the affective as well as the intellectual faculties. If along with the higher powers it be applied to ideas and conceptions of importance, its agency is called *wit;* directed to common events and lesser notions, it appears as *humour;* in union with Constructiveness and Configuration, it produces caricatures and pictures, in the manner of Hogarth and of Callot; acting unattended with Benevolence, particularly if Combativeness and Destructiveness be large at the same time, it originates satire and sarcasm. In short, jest, raillery, mockery, ridicule, irony, and every turn of mind or action that excites mirth, gaiety, and laughter, result from this sentiment. In the writings of Voltaire, Rabelais, Sterne, Prior, Boileau, Swift, &c., its activity is clearly perceived.

There is, perhaps, not anything in the world so universally admired as Wit, and there is hardly a subject upon which so great a diversity of opinion exists, or a subject more difficult of definition. To fix the ultimate root of the word, we should have to go to the ancient languages of the East. Yet wit, as a recognised English word and a simple term, is, to all practical purposes, a *base*, or, more properly, an *English base.* "To wit," with our Anglo-Saxon forefathers, and for many centuries afterwards, signified to know; and hence the old-fashioned phrase '*wist ye not*," or "*know ye not.*" But *knowing* is a very comprehensive idea. There are many things connected with it which require distinct names. Accordingly, from *wit* there have been successively derived *witty*, the *wits*, a *witness*, *wise*, *wisdom*, a *witch*, a *wizard*, a *witling*. Now these terms, it will immediately be seen, are all related in their signification, either directly or indirectly, or collaterally, to the original WIT. It will also be observed, that they have been formed by making slight additions to that word, which is consequently the English root.

Mr. Combe observes, everybody knows what wit is; and, as everybody knows, he has not given us any definition of his own, but acknowledges the difficulty.

In observing the portraits or busts of Sterne, Swift, Thomas Hood, or Charles Dickens, the upper and outer parts of the forehead, immediately before the organ of Ideality, will be seen freely developed. But yet in all these the wit will be very differently displayed, because the other parts of the organization differ in all.

As wit, in combination with the other faculties, must be supposed to take the bent of those which predominate, so the different individuals who have written upon it will be found to have tinged it with their own peculiarities. For instance, Dryden maintains that "wit consists in a propriety of words and sentiments." Yet this must be surely allowed to be nearly as distinct from wit as from nonsense, since it implies merely an accurate use of lexicography; and if this definition be a just one, then Euclid was certainly one of the greatest wits

that ever existed; for where can be found more propriety in the choice of words than in his Elements, which, so far from inspiring mirth, have frequently proved soporific? Locke's definition is nearly as faulty as Dryden's. He says—"Wit lies in the assemblage of ideas, and putting those together with quickness and variety wherein can be found any resemblance and congruity, thereby to make a pleasant picture and agreeable vision to the fancy." This is a tacit censure on his own logic; it is not a general but a particular definition. Pope thus defines wit:—

"True wit is nature to advantage dress'd;
What oft was thought, but ne'er so well express'd."

According to this it almost seems to imply that sheer nonsense, if expressed elegantly, becomes wit.

Sir William Davenant, who wrote a treatise on Wit, is yet another example of false definition. According to him, wit is nothing more than prudent and discreet conduct in our several stations. Here are his own words:—"Wit is, in divines, humility, exemplariness, and moderation [what a witless carle the pope must be!]; in statesmen, gravity, vigilance, benign complacency, secresy, patience, and despatch; in leaders of armies, valour, faithfulness, temperance, dexterity in punishing and rewarding." What a wit the Duke of Wellington must have been! But when his hand was in, it is a pity he had not gone a little further; as thus: Wit, in tanners, is the best method of dressing hides; in carpenters, adroitness in handling their tools; in cutlers, the tempering and sharpening of razors.

In several successive numbers of the "Spectator," Mr. Addison treats of the different sorts of false wit; and censures authors who employ their talents in anagrams, chronograms, epigrams, and puns. In opposition to this, Dean Swift considers the smartness of the epigram indicative of true wit. Thus he says—

"True wit is like the precious stone
Dug from the Indian mine,
Which boasts two various powers in one—
To cut as well as shine.
Genius, like that, if polish'd right,
With the same gift abounds;
Appears at once both keen and bright,
And sparkles while it wounds."

We see then that Dryden, Locke, Pope, Sir William Davenant, Addison, Swift, all considered eminent wits in their day, oppose each other in their definition of it, as well as in its functions.

The late Rev. Sidney Smith describes wit as the flavour of the mind; and we cannot refrain from quoting his view of it:—

"Almost all the great poets, orators, and statesmen of all times, have been witty. Cæsar, Alexander, Aristotle, Lord Bacon, were witty men. So were Cicero, Demosthenes, Shakspeare, Boileau, Fontenelle, Ben Jonson, and most men who have made a figure in the House of Commons.

"I have talked of the danger of wit. I do not mean by that to enter into commonplace declamation against faculties, because they are dangerous. Wit is dangerous. Eloquence is dangerous. A talent for observation is dangerous. Everything is dangerous that has efficacy and vigour for its characteristics. Nothing is safe but mediocrity. The business is in conducting the understanding well to risk something, to aim at uniting things that are commonly incompatible. The meaning of an extraordinary man is, that he is *eight men*, and not one man; that he has as much wit as if he had no sense, and as much sense as if he had no wit; that his conduct is as judicious as if he were the dullest of human beings, and his imagination as brilliant as if he were irretrievably ruined. But when wit is combined with sense and information, when it is softened by benevolence and restrained by strong principle, when it is in the hands of a man who can use it and despise it, who can be witty and something much better than witty; who loves honour, justice, decency, good-nature, morality, and religion ten thousand times better than wit—wit is then a beautiful and delightful part of our nature. There is no more interesting spectacle than to see the effects of wit upon the different characters of men—than to observe it expanding caution, relaxing dignity, unfreezing coldness, extorting reluctant gleams of pleasure from melancholy, and charming even the pangs of grief. It is pleasant to observe how it penetrates through the coldness and awkwardness of society, gradually bringing men nearer together, and, like the combined force of wine and oil, giving every man a glad heart and a shining countenance.

"Genuine and innocent wit like this, is surely the *flavour of the mind.* Man could direct his ways by plain reason, and support his life by tasteless food; but God has given us wit, and flavour, and brightness, and laughter, and perfumes, to enliven the days of man's pilgrimage, and to charm his pained steps over the burning marl."

Before introducing to our readers illustrations of wit, we will glance at the opinion of the eminent phrenologist Combe; but we may previously remark, that the ludicrous owes its origin to the contrariety between the parts or means as perceived by Wit, and the general whole or purpose perceived by Comparison, or the necessary connection perceived by Causality: therefore gaiety, mirth, and laughter arise from the mutual influence and reaction of the feelings. Some kinds of congruity and incongruity excite one class of feelings, other kinds altogether different feelings, and, consequently, according to the faculty or combination of faculties affected, the kinds of mirth and laughter may be varied from the sardonic grin of Destructiveness to the lover's smile.

We must not imagine, however, that wit is the invariable provocative to laughter. There may be much sterling wit without anything tending to absolute risibility of the muscles. Mr. Combe introduces into his system the following example, to prove that wit does not always promote laughter:—

"There is a story of a Nottinghamshire publican, Littlejohn by name, who put up the figure of Robin Hood for a sign, with the following lines below it:—

"All ye who relish ale that's good,
Come in and drink with Robin Hood.
If Robin Hood is not at home,
Come in and drink with Little John."

"This is genuine wit of its kind, yet it does not force us to laugh. But Mr. Littlejohn having died, his successor thought it a pity to lose so capital a sign, and so much excellent poetry, and accordingly retained both; only, erasing his predecessor's name, he substituted his own in its place. The lines then ran thus:—

"All ye who relish ale that's good,
Come in and drink with Robin Hood.
If Robin Hood is not at home,
Come in and drink with *Samuel Johnson.*"

"The whole wit is now gone, and yet the lines are much more laughable than before."

In his work on the "Anatomy of the Brain," Dr. Spurzheim shows that Ideality and Wit belong to the same department of convolutions, whence a presumption in his opinion arises, that their functions belong to the same class of mental faculties, and as Ideality has been uniformly regarded as a sentiment, Wit may with propriety be so denominated also.

All the differences regarding wit which we have brought forward, relate principally to the metaphysical analysis of the faculty. Phrenologists are agreed on the fact, that witty and mirthful manifestations depend upon a particular portion of the brain; but wit will at all times be exhibited variously, according to the combination of faculties which influence it.

Thomas Hood is the only wit we have space to illustrate. His portrait presents a striking exemplification of the organ, and the intellect, viewed as a whole, is altogether superior. He was requested to write a short biography of himself, but he sent his reasons for declining; which reasons are admirably adapted to show his wit. He thus writes of himself:—

"My whole course of existence, up to the present moment, would hardly furnish materials for one of those *bald biographers* that content the old gentlemanly pages of *Sylvanus Urban.* Lamb, on being applied to for a memoir of himself, made answer that it would go into Egyptian epigram; and I really believe that I could compress my own into that Baker's dozen of lines called a 'SONNET.' Montgomery, indeed, has forestalled the great part of it in his striking poem on the '*Common Lot.*' But in prose nobody would make anything of it but *Mr. George Robins.* My birth was neither so humble that, like *Tom Jones,*

I have been obliged among my *lays* to *lay the cloth*, and to *court the Cook and the Muses* at the same time; nor yet so lofty, that with a certain lady of title I could not write without letting myself down. Then for education, though on the one hand I have not taken any degree with *Blucher*, yet, on the other, I have not been rusticated at the *Opera Air School*, like the *Poet of Helpstone.* As for incidents of importance, I remember none, except being drawn for a soldier, *which was a hoax*, and having the opportunity of giving a casting vote on a great parochial question; *only I didn't attend!* I have never been even a third in a duel, or crossed in love. The stream of time has flowed on with me very like that of the new river, which, every body knows, has so little romance about it, that *its head* has never troubled us with a *tale.* My own *story*, then, to possess any interest, must be a *fib.* Truly given, with its egotism or its barrenness, it would look too like the chalked advertisements on a dead wall. Moreover, Pope has read a lesson to *self-importance* in the 'Memoirs of P. P., the Parish Clerk,' who was only notable, after all, amongst his neighbours, as a swallower of LOACHES.

"To conclude: My life, upon my life, is not worth giving or taking. The PRINCIPAL just suffices for me to live upon; and, of course, would afford little INTEREST to any one else. Besides, I have a bad memory, and a personal history would assuredly be but a *middling* one, of which I have forgotten the *beginning*, and cannot foresee the end. I must, therefore, respectfully decline giving my life to the world, at least till I have done with it."

With an illustration of Mr. Hood's poetic wit, we conclude this organ:—

"O bed! O bed! delicious bed!
Thou heaven upon earth to a weary head,
But a place that to name would be ill bred,
To the head with a wakeful trouble—
'Tis held by such a different lease,
To one a place of comfort and peace,
All stuffed with the down of stubble geese;
To another with only the stubble.

To the happy, a first-class carriage of ease,
To the land of nod, or where you please;
But, alas! for the watchers and weepers,
Who turn, and turn, and turn again,
But turn, and turn, and turn in vain,
With an anxious brain,
And thoughts in a train
That does not run upon *sleepers.*

And oh! when the blessed diurnal light
Is quench'd by the providential night
To render our slumber more certain,
Pity, pity the wretches that weep,
For they must be wretched who cannot sleep,
When nature herself draws the curtain.

The careful Betty the pillow beats,
And airs the blankets and smooths the sheets,
And gives the mattress a shaking;
But vainly Betty performs her part,
If a ruffled head and a rumpled heart,
As well as the couch, want making.

There's Morbid, all bile, and verjuice, and nerves,
Where other people would make preserves,
He turns his fruit into pickles;
Jealous, envious, and fretted by day,
At night to his own sharp fancies a prey,
He lies like a hedgehog rolled up the wrong way,
Tormenting himself with his prickles.

But a child that bids the world good night
In downright earnest, and cuts it quite—
A cherub no art can copy:—
'Tis a perfect picture to see him lie,
As if he had supp'd on dormouse pie,
(An ancient classical dish, by-the-by,)
With a sauce of sirup of poppy.

O bed, bed, bed! delicious bed!
That heaven upon earth to a weary head,
Whether lofty or low its condition!
But instead of putting our plagues on shelves,
In our blankets how often we toss ourselves,
Or are toss'd by such allegorical elves
As pride, hate, greed, and ambition."

21. IMITATION.—The organ of Imitation lies on either side of Benevolence. If both of these organs be large, the superior anterior portion of the head is elevated in a hemispherical form; but when the organ of Benevolence alone is large, and that of Imitation small, there is an elevation in the middle, and a declivity at the sides.

Of the discovery of this organ Dr. Gall remarks:*—"When I was talking with one of my friends respecting the form of the head, he assured me that his own was a very peculiar one. He then directed my hand to the anterior superior part of the head. I found this region considerably bulging; and behind the protuberance, a depression, a cavity, which descended on each side towards the ear. Prior to this period, I had not observed this conformation. This man had a peculiar talent for imitation. He imitated, in so striking a manner, the gait, the gestures, the sound of the voice, &c., that the person was immediately recognised. I hastened to the Institution for the Deaf and Dumb to examine the head of the pupil Casteigner, who had been received into the establishment six weeks previous, and who, from the first, had fixed our attention by his prodigious talent for imitation. On Shrove-Tuesday, when a little theatrical piece is usually represented in the establishment, he had imitated so perfectly the gesture, the gait, &c., of the director, inspector, physician, and surgeon of the establishment, and especially of some women, that it was impossible to mistake—a scene which amused the more, as nothing like it was expected from a boy whose education had been absolutely neglected. To my great astonishment, I found in him the superior anterior part of the head as prominent as in my friend Annibal.

"Can the talent for imitation, I asked myself, be dependent on a particular organ? And I sought opportunities for multiplying my observations. I visited families, schools, &c., and examined the heads of individuals who possessed the talent for imitation in an eminent degree. At this period, M. Maix, secretary to the Minister of War, had gained great reputation by several parts which he played in a private theatre. I found in him the region of the frontal bone alluded to, as prominent as in Casteigner and Annibal. In all the other persons whom I examined, I likewise found this region more or less prominent, according as they were endowed with the talent of imitation to a greater or less degree.

"They relate of Garrick, that he possessed a faculty of imitation so astonishing, that he forgot nothing of the retinue of the court composed of Louis XV., the Duke of Aumont, the Duke of Orleans, of Bussac, Richelieu, and others. All these personages, whom he saw once passing by, were fixed in his memory. He invited to supper the friends who had accompanied him, and impatient to amuse them, said to them after supper—'I hove seen the court only an instant, but I am going to prove to you the accuracy of my eye and the excellence of my memory.' He then arranged his friends in two lines, went out, and an instant after returned. All the spectators exclaimed—'There is the king! there is Louis XV.' He imitated, in succession, all the personages of the court; they were all recognised. Not only had he imitated their gait, their walk, their figure, but even the lines and the character of their physiognomy. I soon considered that this faculty must constitute a considerable portion of the talent of the comedian. I therefore examined the heads of the best actors which we then had, and in all I found the region alluded to prominent.

"In our travels, M. Spurzheim and myself found the same organization in all the great comedians we had occasion to examine. It may be observed in all eminent dramatic writers, Terence, Shakspeare, Corneille, Moliere, Voltaire, &c."

The function of this organ may be stated as disposing to imitation in general. Its most energetic development is often displayed by mimicry; but the nature of things or persons imitated depends much upon the combination of powers which influence it. A good ear, an endowment of Time and Tune in fair proportion, aided by Language and Secretiveness, appears to me to be of essential consequence in the formation of a ventriloquist. In imitations of this description, it appears also necessary to have a good knowledge of space, so that the voice may be exactly modulated to convey illusions of a sound from a distance. Tact, which depends much upon Secretiveness, seems essential to this species of deception; but it is evident that Imitation is the most important faculty required.

A pompous person will be best imitated by one who, to a free development of the organ in question, adds large Self-Esteem, and a vain person by large Love of Approbation. The successful imitator of actors must, in addition to well-developed

* Works, Vol. V. p. 201.

reflecting faculties, to enable him to judge of the real qualities of the person he imitates, also have large Secretiveness, in order that he may suppress his own natural character.

In some artists we have observed this faculty developed with great power. We are acquainted with a most exemplary man, of the strictest integrity, who has a wonderful talent for caricaturing. In him, Imitation is essentially large, as are also Form, Size, Colouring, Wit, and Locality. During the controversy, some years ago, between the Established Church and the Voluntaries, he painted three caricatures, placing, in the most ludicrous and sarcastic positions imaginable, the churchmen. They are fearful evidences of the power of mimicry, and, were they published, would inflict more pain upon the Church party than all the Voluntary lectures put together.

Dr. Gall remarks, that the talent for imitation will manifest itself, with so much the more energy and extent, as it is accompanied with a greater vivacity of feeling, and a greater number of other distinguished faculties. The variety of other organs which accompany that of Imitation, constitutes the difference in actors. The parts of waiting-maids, valets, simpletons, buffoons, fops, lovers, coquettes, tyrants, sharpers, demand each a peculiar energetic disposition. And if an actor is equally great in opposite parts, we must conclude, either that he has a complicated talent, or that he is indebted rather to study than to nature for his success.

MECHANICAL DRAWING.

CHAPTER XII.

To delineate the "eccentric" arms of a turbine, as shown in fig. 86. Draw the two diameters in the internal circle, fig. 86. The radii of both arms are equal; so that it will be sufficient to describe the half of the figure in the upper side of the line *a b*, fig. 87. Find the centres of the various arcs; they will be found at the points *a b*, *c d e*, fig. 86. By operations identical with those already described in figs. 83, 84, &c., find the points *h*, *c*, *d*, *e*, *f*, in fig. 87, corresponding in position to *a b*, *c d e*, in fig. 86. From the point *c*, fig. 87, with radius *c g* (obtained from fig. 86), describe the arc *g i*. From *d*, the arc *i k*; from *f*, the arch *h m*, joining the semicircle described from *h*. Finally, from the point *e* describe the arc *n*, joining that described from *f* in *f m*. Finish as in fig. 86.

A curved irregular outline, in fig. 90, may be delineated, as in fig. 91, by means of points. Draw any number of lines across the figure to be copied, as in fig. 90, at right angles to the base line, *a b*, as 1, 2, 3, &c. Draw, in fig. 91, a line, *a b*, corresponding to *a b*, fig. 90, and set off in it divisions, equal to those in *a b*, fig. 90, starting from the point, *b*. Then proceed, by taking the distance from the points in *a b*, to the points where the curved line intersects the lines from the points in *a b*, as *b c*, 5 *d*, 8 *e*, 14, *h*, *a i*, and so on; and transfer them to the corresponding divisions on the line, *a b*, fig. 91; and through the points thus obtained, as *b c*, 5 *d*, 8 *e*, &c., fig. 91, draw the curve; it will be a fac-simile of fig. 90.

Irregular figures, as in fig. 92, can be copied with much facility, by drawing a series of lines across it at right angles, and at *equal* distances from each other; forming, on the face of the figure to be copied, a series of *squares*. A similar series of squares is next to be formed, as in fig. 93; and the points at which the curves, or lines of the figures, in fig. 92, cross the lines, or are situated within the squares, are to be transferred to the corresponding points in fig. 93. The operation will be much facilitated by the lines being numbered correspondingly in both diagrams. The points of intersection and position will be in this way much more easily ascertained. Thus, the point, *a*, is on the point of intersection of the 10 vertical line and 7 horizontal; thus it is immediately ascertained. The distances of various points, *not on* the intersection of lines, but between the squares, as the point, *c*, may be ascertained by measuring with the compasses its distance from any line, as the point 6, and transferring it to the corresponding line in the other figure. This method of copying is much practised by engineers, &c.

We cannot sufficiently impress on the mind of the learner, who is desirous to obtain a speedy facility in copying and laying down drawings, the importance of devoting a good portion of his time, at the first outset, to the copying of simple and detached figures. The time devoted to this apparently simple practice is by no means lost. Experience has proved to us, that attention to the simple details, such as we have already given, is the true way to make a quick and accurate draughtsman. It is with this view that we add a few more examples, in which the formation of habits of quick analysis of the various points of a drawing will be still further aided.

Figs. 94, 95, are delineations of parts of punching machines. To delineate the diagram in fig. 94, find the centres of the various arcs, as at *a*, *b*, *c*, *d*, *e*. Draw two lines, *f g*, *g h*, at right angles, as in fig. 95, corresponding to similar lines in fig. 94. Make *g f*, fig. 95, equal to *g f*, fig. 94. From *g*, with *g b*, fig. 94, describe an arc, and from *f*, with *f b*, another, cutting this in the point, *b*, fig. 95. With *g d*, *b d*, fig. 94, from the points, *g*, *b*, describe arcs cutting one another in the point *d*, fig. 95. With *g e*, *d e*, from fig. 94, from the points, *g d*, fig. 95, describe arcs cutting in *e*. With *b a*, *d a*, fig. 94, from points, *b d*, fig. 95, describe arcs cutting in *a*. With *b c*, *a c*, fig. 94, from the points, *b a*, fig. 95, describe arcs cutting in *c*. From centre, *b*, with radius obtained, from fig. 94, describe the arc, *g m*; from *d*, the arc, *d n*; from *e*, the arc, *n o*; and from *a c*, the arcs meeting in *s*. Finish as in fig. 94.

To delineate fig. 96, find the centres, as at *a b*; draw, as in fig. 97, a line, *c d*, equal to corresponding line in fig. 96. With the distances, *d b*, *c b*, from fig. 96, from the points, *c d*, fig. 97, describe arcs cutting in *b*. With the distances, *c a*, *b a*, fig. 96, describe arcs from the points, *c*, *b*, cutting each other in *a*. From *b*, with radius obtained from fig. 96, describe the arc, *c e*, and from *a*, the arc, *a f*. Finish as in fig. 96.

To delineate the curved "lever" in fig. 98, find the centres of the various circles and curves, *c d*, *g f*, *a b*. Draw a circle equal to *a*, and put the diameters as in the diagram. Through *a* draw a line to *e*, and in the copy make a line equal to this. The centre of the circle, *b*, is obtained by describing arcs with radii, *a b*, *e b*, from the points, *a e*, cutting in *b*. The centre, *f*, by arcs, *b f*, *e f*, described from the points, *e b*. The centre, *g*, by arcs described from *b* and *f*, with radii, *b g*, *f g*. The centre, *c*, by arcs from the points, 1, 2, with radii, 1 *c*, 2 *c*. The centre, *d*, from same points, with radii, 1 *d*, 2 *d*. The centre, *m*, by arcs described from the points, *d b*, the radii being *d m*, *b m*. The arc 3 *h* is described from the centre, *d*; *h m* from *m*; the arc, *n*, from *g*; the arc, *o*, from *f*; and *s* from *c*.

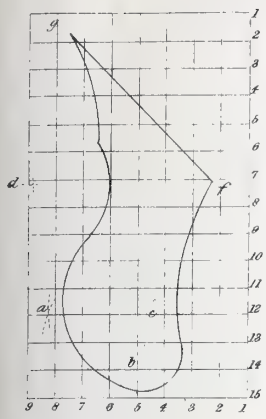
The diagram in fig. 99 is delineated by processes the same as those already detailed. Find the centres of the arcs, as at *a*, *b*, *c*, *d*, and *e*. Describe a circle from *b′*, fig. 100, equal to that described from *b*, fig. 99. Draw the diameter, *b′*, with *c b c*, from fig. 99. Describe arcs cutting in *c′*, fig. 100. With *c d*, *b d*, from the points, *c′ b′*, describe arcs cutting in *d′*. With *b e*, *d e*, fig. 99, from points, *b′ d′*, describe arcs cutting in *e*. With *b c*, fig. 99, from points, *b′ c′*, describe arcs cutting in *m*. From *c*, as a centre, describe the arc, *f′ h*; from *d′*, *h n*; from *e*, *m m*; and from *m*, the arc, *n n*; take the distance, *b f*, from fig. 99, and cut the arc, *n n*, in the point, *o*, fig. 100; take *f g* from fig. 99, and from the point, *o*, fig. 100, cut the arc, *m m*, in the point, *m*; join *m o*.

The diagram in fig. 101 shows the method of copying fig. 90 by squares; fig. 102 that of fig. 97; figs. 103 and 104 that of figs. 98 and 99, respectively.

Fig. 105 illustrates the method of enlarging the scale of a diagram by means of the squares. The figure is the same in outline with fig. 92; but the size of the squares is double that of fig. 92. This is done by making the distances between the lines forming the squares twice that in fig. 93. It is obvious that from this principle a drawing may be reduced or enlarged in any proportion required.

Fig. 106 further illustrates the facilities which this method of copying offers to the draughtsman. In this case the diagram in fig. 105 is reversed; the line, *a b*, to the left, in fig. 105, is placed to the right in fig. 106. This is done by merely reversing the rotation of the figures denoting the different squares: thus, the point, *c*, in both cases, is obtained by the intersection of the seventh horizontal line with the tenth vertical.

99



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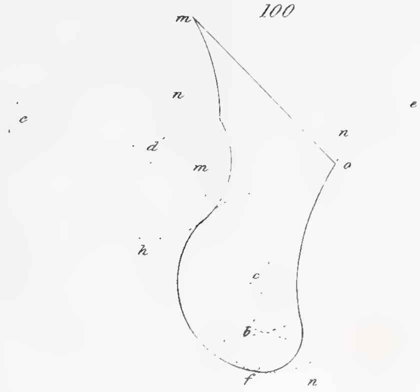

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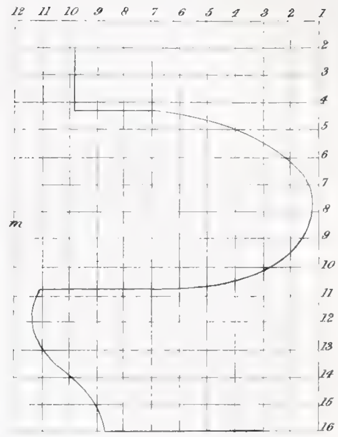

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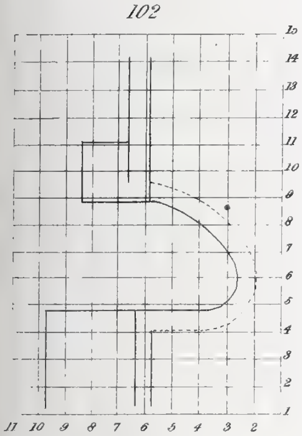

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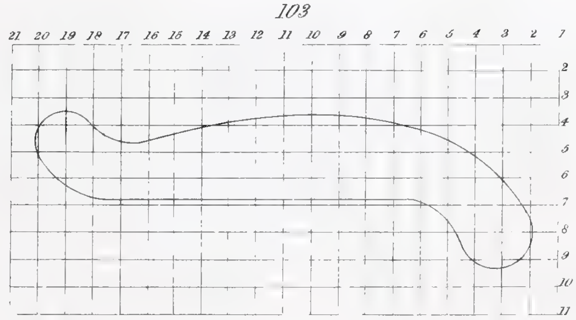

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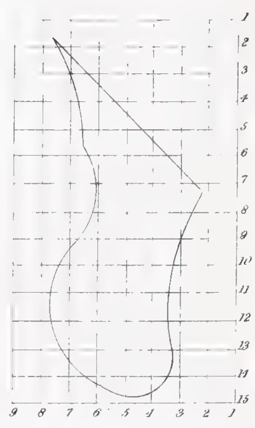

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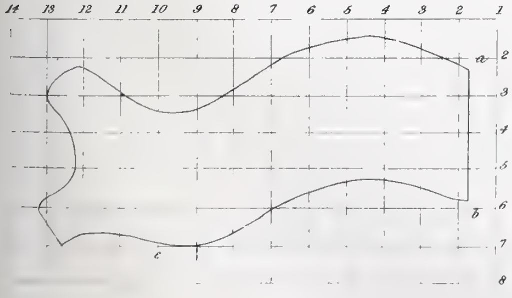

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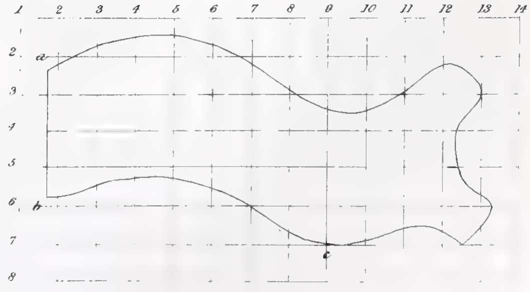


TERMS USED IN MECHANICS.

V. THEORY OF THE FLY-WHEEL

On the common form of Fly-Wheels, and their ratio of vis viva.

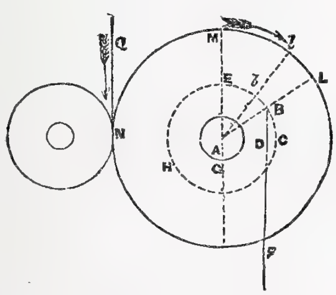
It is not always possible to regulate the force of a moving power, or the resistance to its motion, as is often attempted, by the use of double or triple cranks; and when it is necessary that one only should be used, the variations that occur in the resistance make sensible changes in its speed. Thus, it is under these circumstances that at one time the power is greater than the resistance, and at others the resistance overwhelms the power, so that the speed is ever changing. To render this motion regular, we have recourse to the fly-wheel. This is generally composed of a ring of cast-iron of a rectangular section, attached to a set of arms radiating from one common axis. Sometimes also a lenticular form is given to the arms, with the view of diminishing their resistance to the atmosphere; but this form is one which is open to serious objections. In order to arrive at the amount of inertia of a fly-wheel, let us suppose P to represent its weight, V the amount of motion of the centre of its periphery during one second of time, then

$$\frac{P}{g} \times V^2$$

is the amount of *vis viva* of the fly-wheel, V^2 being equivalent to the product of the angular velocity and the mean radius.

Fly-wheel for a Single-acting Crank.

We shall now enter upon the consideration of the theory of such examples of fly-wheels as oftenest occur in practice; and, referring to the annexed wood cut, let us suppose A B to be a crank revolving on its axis A, and in the act of being drawn downwards by a force F, which acts only during the semi-revolution of the crank pin,—namely, from E to G. M is a spur wheel keyed upon the axis of the crank and gearing, with a second one at N, at which point a reactive force, arising from the resistance which is offered to the motion of the wheel, acts in the direction Q N.



In this calculation we shall take no account of the inertia of the wheel M, as its diameter is exceedingly small in comparison with that of the fly-wheel, the great mass of metal in which is always placed as far as possible from the axis of rotation, in order to obtain a great amount of *vis viva*. Under these conditions, we must observe that the labouring force of the pressure F upon the crank-pin is continually changing; it increases gradually from E to C, and in like manner it decreases from C to G, when it is *nil*, in which state it remains during the remaining semi-revolution G H E. During this whole revolution of the crank, the reaction Q, as it is always tangential to the circumference of the wheel, is necessarily constant throughout. In proportion as the labouring force of the power F acts upon the resistance at Q, the velocity increases; but it is impossible that this can happen to an indefinite extent, as the labouring force gradually diminishes until it arrives at that point, when it becomes equivalent only to the offered resistance, its power then becoming a maximum. The labouring force again gradually diminishes, until it becomes less than the amount of resistance; and from this new inequality, which is the converse of the former, results the gradual diminution of the velocity. But as the labouring force cannot decrease infinitely, and as, owing to the continuous revolution of the crank, it will again increase, we perceive that so long as it remains less than that of the resistance, the diminution of the speed continues until it arrives at that point when the labouring force will equal that of the resistance. At this moment the speed has arrived at its minimum, and the labouring force gradually overcomes the resistance, the speed again increasing, until it again arrives at its maximum.

If now we suppose a fly-wheel of considerable momentum to be fixed on the axis A, and referring to the two points of its revolution, when the velocity of the system is greatest and least, it is evident that the momentum of the fly-wheel will also be increased and diminished at these two points, and this variation in the momentum ought to be equal (allowing for the power absorbed by the other portions of the machinery,) to double the absolute difference between the labouring force of the power and that which is expended in overcoming the resistance during the intervals of the two points corresponding to the greatest and least velocity. This theory may be easily proved, as we have the means of calculating the labouring power of the different forces in action. The momentum of the fly-wheel, as we have previously observed, is

$$\frac{P}{g} \times V^2 \text{ or } \frac{P}{g} \times A^2\, v^2$$

Here A represents the radius of the wheel, and v its angular velocity, which is proportionate to the number of revolutions of the fly-wheel in a given time; bearing in mind that with a given speed the momentum is in proportion to its weight and the square of the radius, so that by doubling or tripling the radius of a wheel, we obtain a force four or nine times greater. If now we observe the points at which the speed of the system is accelerated, the momentum which the fly-wheel absorbs is again equivalent to twice the labouring force of the pressure diminished by that of the resistance; and under these circumstances, supposing the labouring force to remain the same, it is obvious that the angular velocity of the fly-wheel becomes less as its weight and radius are increased. It is in this manner that we regulate the weight and diameter of the wheel, that its angular velocity may not be beyond certain limits above or below which a variation of one-tenth only is allowed.

Admitting that in the resistance, Q, is included that of friction, previously determined by calculation, this friction is to be multiplied by the ratio of the radius of the axle of the wheel M to the radius A N, to which must be added the variable resistance of the other wheel. The first condition to be fulfilled is that at the end of each revolution the total labouring force of the pressure F must be equal to the resistance Q. But if in the first instance the power was greater than the resistance, then the speed would gradually increase, losing all uniformity of motion. Referring back to our former diagram, we have the labouring force F during the first semi-revolution E C G, $F \times E\,G$, or $F \times 2r$; and as the power during the ascending semi-revolution is *nil*, it is evident that the product of $F\,2r$ represents again the labouring force during one complete revolution. On the other hand, the resistance Q, which does not cease to act tangentially upon the wheel M, whose radius we will represent by R, during the whole of the revolution, this power again will be $2\,\pi.\ R.\ Q$. Then, by virtue of the first conditions announced, we have $F.\ 2r = 2\,\pi.\ R.\ Q$, and consequently,

$$Q = \frac{F.\ r}{\pi\,R} \quad \ldots\ldots \quad (a)$$

This is the value of the resistance to motion which the power has to counteract. Let us find exactly the positions of the crank at which the velocity of the fly-wheel arrives at its two extremes.

To this end, referring to the labouring force F, at the point B, which we before found to be equal to $F \times \frac{s}{r} \times A\,D$.

Suppose, now, the crank-pin to be placed at the point E, and caused to move from left to right, it is obvious that in this central position the power is *nil*, although the resistance is always acting; nevertheless, the crank being caused to revolve, if the power does not again act with a preponderance in its favour, the labouring force is increased; thus the velocity is not diminished until the crank-pin arrives at the point B, when the labouring power again becomes equal to the resistance. But whilst the crank-pin describes the short arc b B. which we shall denominate s, the point of application of the resistance Q describes upon the circumference of the wheel M an arc l L, similar to b B, and thus we have

$$l\,L : b\,B, \text{ or } s :: R : r,$$

$$\text{or } l\,L = \frac{R}{r} \times s,$$

The point B, where the two labouring forces are equal, is moreover that at which the velocity of the fly-wheel does not diminish; and this will be determined by the relation of the equality of the labouring force of the power and resistance.

$$F \times \frac{s}{r} \times A\,D = Q \times L\,l,$$

or, substituting l L for the whole value found at this instant,

$$F \times \frac{s}{r} \times A\,D \times = Q \times \frac{s}{r} \times R.$$

This formula being reduced, becomes definitively

$$F \times A\,D = Q \times R.$$

Substituting for Q the value (a), we find again,

$$F \times A\,D = \frac{F.\,r}{\pi\,R} \times R,$$

$$\text{or } A\,D = \frac{r}{\pi} = 0{,}318,\ r.$$

This then is the value A D, that is to say the distance from the centre A, of the perpendicular pressure upon the point sought, B, on the horizontal line A C. This distance is, as we have previously observed, equal to one-third of the radius of the crank.

At the moment that the crank-pin passes the point B, the labouring force overcomes that of the resistance, and the velocity is accelerated until the two renewed labouring forces are made equal; at this time the velocity of the fly-wheel is at a maximum. This point is evidently beneath the horizontal line A C, because the radius of the labouring force of the pressure is at its maximum, and it will diminish again to become equal to that of the resistance. Again, let the position B' of the crank-pin be that at which it attains its greatest velocity, which we obtain by the same calculations as before, being determined from the value A D, being 0.318, r; this proves that the points B and B', at which the velocity of the fly-wheel is respectively a minimum and maximum, are upon the same line perpendicular to the horizontal line A C, and at the given distance 0·318 r from the centre. After passing the point B', the labouring force of the pressure is less than that of the resistance; and during the ascending semi-revolution it remains at *nil*, thus the speed is decreased, and again arrives at its minimum as before when the crank-pin reaches the point E. In a word, the action of the power varies in a similar manner during each revolution, the velocity becoming the same upon the crank-pin resuming the same positions.

To calculate the weight of a fly-wheel we shall consider what takes place during that portion of its travel comprehended between the points B and B'. Putting V to represent the maximum velocity of the fly-wheel, taken at the centre of the rim, which takes place when the fly-wheel is at B', then

$$\frac{P}{g} \times V^2$$

will be the *vis viva* of the fly-wheel at the instant of the crank's position at B, and v represents the minimum velocity of the fly-wheel.

$$\text{Thus, } \quad \frac{P}{g}\,V^2 - \frac{P}{g}\,v \quad \text{or, } \frac{P}{g} - (V^2 - v^2)$$

expresses the increment of the *vis viva*, which is absorbed by the fly-wheel during the interval of the two positions B B' of the crank. The labouring force of the power F during the same interval being F × the chord B B', otherwise we have the chord B B' = 2 B D,

$$B\,D = \sqrt{A\,B^2 - A\,D^2} = \sqrt{r^2 - (0.318.\ r)^2} = 0{\cdot}948.$$

$$\text{or } B\,B' = 2 \times 0.948,\ r, = 1.896,\ r.$$

The product F × the chord B B' then becomes 1·896 r. F. If now we have given the labouring force of the resistance Q, acting during this interval, which is equivalent to the product of Q multiplied by the arc which the point of application describes during the time that the crank-pin describes the arc B B', or, in other words, it is equal to Q × arc B B', $\times \frac{R}{r}$. Or by the use of a table of arcs and corresponding chords, knowing that the chord B B' = 1·896, r, we find the arc B B' = 2.4938 r. Consequently, the labouring force of the resistance is thus found,

$$Q \times 2{\cdot}4938,\ r. \times \frac{R}{r}, \text{ or } Q \times 2{\cdot}4938,\ R.$$

Substituting again the expression Q for the value given according to the first condition, which is $\frac{F\,r}{\pi\,R}$, we find the labouring force to be equal to

$$\frac{F\,r}{\pi\,R}.2{\cdot}4938,\ R, \text{ or } F\,\frac{2{,}938,\ r}{\pi}, \text{ or } 0{\cdot}7938\ r\ F.$$

The excess of the labouring force of the power over that of the resistance is evidently r F (1·896 — 0·7938), that is 1·102 r F, the double of which, 2·204 r F, is equivalent to the increment of the *vis viva* of the fly-wheel, or

$$\frac{P}{g}(V - v).$$

We shall then have this equation,

$$\frac{P}{g}(V^2 - v^2) = 2{\cdot}204,\ r\,F \quad \ldots\ldots \quad (b)$$

If the weight of the given fly-wheel is to be such that its velocity shall never vary more than 1-10th, or, in general terms, $\frac{1}{n}$, it is obvious that its maximum and minimum speeds will be represented, the one by $V^1 + \frac{v'}{n}$ and the other by $V^1 - \frac{V^1}{n}$. Thus the three speeds, V, V^1, and v, form a proportional difference between each other, of which the ratio is $\frac{V^1}{n}$; thus V is greater than this quantity $\frac{V^1}{n}$, by the velocity V, which is greater than the velocity v by an equal amount, that is, V is greater than v by double $\frac{V^1}{n}$

$$\text{Then} \qquad V = v\,\frac{2\,V_1}{n}, \text{ or, } V - v = \frac{2\,V_1}{n}$$

But it is easily seen that if

$$V = V_1 + \frac{V_1}{n} \text{ and } v = V - \frac{V}{n}$$

we have likewise $V + v = 2\,V_1$.

Then if we multiply $V + v$ by $V - n$, and remembering that the product of the sum of two quantities by their difference is equal to the difference of their squares, we con-

clude that $V^2 - v^2 = \frac{4 V_1^2}{n}$. Substituting this last expression for the relation (*b*) of the fly-wheel, we find,

$$\frac{P}{g} \times \frac{4 V^2}{n} = 2\cdot204, r F,$$

and, consequently, $P V_1^2 = 2\cdot204 \times \frac{g.n}{4} r. F.$

But we obtain the mean velocity V_1 of the fly-wheel from the number of revolutions which it makes in a given time, and from its radius. Consequently we arrive at this final equation, which gives us the weight P of the fly-wheel.

But the expression $P V_1^2$ of the product may be arrived at in another form, and the number of horses power or the power which constitutes the labouring force of the machine by the number of revolutions which the fly-wheel makes in a given period, one minute for example: if now we call this effect *m*, and the latter number $2 m r$ F, the labouring force of the machine during one minute, and $\frac{2 m r F}{60}$ or $\frac{m r F}{30}$ will be its amount during one second. Putting N for the number of horses power of the machine, and its amount of labouring force at 75 kilogrammes,* elevated to a height of 1 metre,† in one second we have

$$\frac{m r F}{30} = 75\cdot k m \times N \text{ or } r F = \frac{30\cdot75 N}{m} = \frac{2250\cdot N}{m}$$

Then recalling the relation *r* F for this value, in the expression $P V_1^2$, we find,

$$P V_1^2 = 2.204 \times \frac{g n}{4} \times \frac{2250 N}{m}$$

and substituting for *g* the value 9m 81, we find this gives

$$P V_1^2 = \frac{24324}{m} \times n \times N \quad . \; . \; . \; . \; . \quad (c)$$

Thus, as we have observed, the number *m* relates to the connecting-rod to which the power is applied, and not to the fly-wheel, if this, as is generally the case, is fixed upon a separate axis from that of the power. The number *n* alone is arbitrary in this case. In fact, the greater the number which *n* represents, so much the less will be the variation of the velocity, and if it is required that the speed should vary very slightly, this can only be accomplished by making the value of $n = 1000$, or if the velocity varies only $\frac{1}{1000}$th more or less, the weight of the fly-wheel will be very great—ten times greater than when *n* equals 100.

Accordingly, all fly-wheels are absorbers of power, and any augmentation in their weight consequently causes a greater absorption, and so far detracts from their practical value as regulators of machinery. For example, a fly-wheel of a weight of 20,000 kilogrammes will produce upon its bearings an amount of friction of 2000 kilogrammes, when the ratio (*f*) of the friction to the resistance is equal to 1-10th. Suppose this fly-wheel makes 30 revolutions per minute, and suppose its journals to be 20 centimetres in diameter, or $\frac{m}{0\cdot60}$ in circumference, the power absorbed by friction during one second of time will amount to $2000\, k \times \frac{o\, m\, 60}{2}$ or $600 k m$ that is to say, that this resistance will absorb an amount of power equal to 8 horses of 75 kilogrammes raised 1 metre per second.

We cannot, therefore, make an arbitrary choice of the number *n*, and this determination depends upon the comparison which it is necessary to make of the relative advantages and disadvantages inherent to it. If these wheels are required to work with extreme regularity, let $n = 15$ or 20; if we reduce the number to 10, they will not work with great uniformity. In England, where they are intended for manufactories, the number *n* is often increased to 30, but this is perhaps too much.

* 2·2 lbs. † 39·38 inches.

On Fly-wheels for Double Cranks.

When double cranks are used in moving machinery, the same system of calculation applies, but in this case the labouring force of the power during a revolution is increased to 4 *r* F. Consequently, because the labouring force is equal to that of the resistance at the end of a revolution, we will put $4 r F = 2 \pi R Q$. The position of the crank-pin or the maximum and minimum velocities are equally different; they are here determined by a separate value, $A D = 0\cdot64 r$.

In short, in calculating the chord which includes in the same semi-revolution the position of the point of minimum velocity with that of the maximum, so that the arc which is subtended by this chord will be found to be the same as before, namely, the difference of the labouring force of the power, and that of the resistance during the interval between the minimum and maximum velocity—if we make the double of this difference equal to the increment of force which the fly-wheel absorbs, and if we further remark that the labouring force of the power during one second is represented by $\frac{4 r F m}{60}$, we have for the fly-wheel of the double crank this relation,

$$P V_1^2 = \frac{4645}{m} n \times N \quad . \; . \; . \; . \; . \; . \quad (d)$$

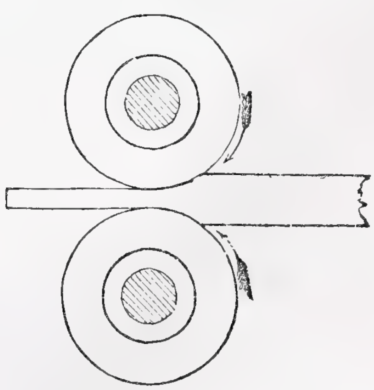
Now, if we compare this expression with that of the single crank, we find it to be similar to it, with this difference, that the numerical factor of the latter is five times greater than that of the former. Therefore, the velocity being equal to that of the former equation, the weight of the wheel must be five times greater. This conclusion demonstrates very forcibly the necessity of regulating the movement as far as possible independently of the employment of the wheel: but its weight may be reduced to one-fourth if the power is distributed over two arms of a double crank of single action, and need not exceed one-tenth if the power is distributed over a triple crank.

Formulæ for Calculating other Fly-wheels.

The preceding examples refer only to fly-wheels for crank machinery driven by steam power, and are inapplicable in a variety of circumstances occurring in practice. In this case the resistance is supposed to be constant, and the direction of the power to be constantly varying according to the angle of the crank. It is often the case that the action of the moving power is constant and the resistance variable, for the reason that the tool, as the saw, which is being driven, has an alternating motion, or because the direction of the resistance is continually changing, or again that the resistance is intermittent.

On Fly-wheels as applied to Rolling Mills.

The rolling mill consists of two iron cylinders, each revolving upon two separate axles; to the converging sides of the surfaces of which, the bars of iron, rough from the forge,



are presented, and being passed through, are delivered out on the diverging side. (See the annexed cut.) In this

manner the iron is flattened and elongated by the pressure it receives from the rollers; but as each bar, after having gone through a pair of rollers, is transferred to a second arrangement, where the surfaces of the rollers are set somewhat closer together, it follows that the resistance is continually intermittent. The motive power, however, continuing to act during these intervals of non-labour, the machine acquires a high velocity at the instant that each bar is presented to the rollers. Immediately this happens, the velocity is diminished, for the reason that the resistance opposed by the iron is greater than the power of the prime mover, and this is reduced to its lowest limits at the time it has passed through the rollers. The determination of the dimension of the fly-wheel is in this case very simple, considering that the maximum velocity corresponds to the instant that the bar is presented to the rollers, and its minimum when it has just passed them.

If, for the sake of argument, we could find the amount of labouring force necessary for passing the bar between the rollers, and the amount of power expended during the passage, the double of this difference is equal to that part of the *vis viva* of the fly-wheel during which it descends from a maximum to a minimum. Putting S for the absolute difference of the two quantities of labouring force, of which that of the iron is by far the greatest, V and v for the maximum and minimum velocities of the mean circumference of the fly-wheel, and P for the weight of the latter, we have

$$\frac{P}{g} \quad (V^2 - v^2) = 2\ S$$

The fly-wheel is fixed on the axis of one of the two rollers, which generally make about 20 revolutions per minute. Thus we find the mean velocity V of the fly-wheel. If, likewise, we have as a condition that the maximum and minimum velocities shall not go beyond that of the regular velocity, or as

$$V^1 \text{ to} \frac{V^1}{n}$$

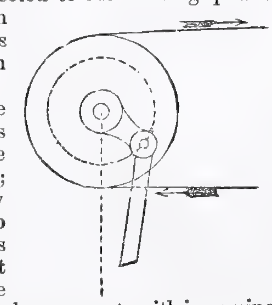
more or less we can effect the calculation for the crank, making $n = 15$ or 20.

We have given, as a primary condition, that the amount of labouring force of the prime mover which is expended during one complete period, or during the time occupied by the passing through of a bar and the presenting another, is equal to the power consumed by the bar, augmented by the resistance caused by friction.

On Fly-wheels applied to Saw Machinery.

The application of the fly-wheel to saw machinery requires a distinct consideration from that used in the case of the rolling mill.

The vertical reciprocating movement is transmitted to the frame of the saw by an intermediate axis, by means of a crank fixed on the shaft connected to the moving power. (See the wood cut annexed.) In this species of crank the saw cuts only during its descent, and in its ascent rises freely.



Thus the crank-pin, during the ascending semi-revolution, is loaded with the weight of the connecting rod and the frame; in descending, on the contrary the crank-pin is favourable to the action of the power, and is pushed downwards by the weight of the connecting rod and frame diminishing the resistance which the saw meets with in passing through the wood. This last, which depends upon the thickness and nature of the wood, may be taken as a mean regular quantity. This done, let us examine from point to point, in the small portions of equal arcs described by the crank-pin, the variations of the labouring force during one complete revolution. The points where these labouring forces shall become equal will obviously be those where the velocities are a maximum and minimum.

If, in continuation, we calculate the total amount of labouring force expended by the power and by the resistance during the interval between the maximum and minimum velocities, and make the double of this difference equal to the increment of *vis viva* of the fly-wheel, we must deduct the weight of the latter for the velocities within the limits assigned.

On Fly-wheels applied to Spinning Mills.

In certain species of machinery it is absolutely necessary that their component parts should have a continuous motion, otherwise their operations will be characterised by a great amount of irregularity. In this class may be included spinning machinery, which, together with the looms for weaving, are driven by the same power. These machines are, as a necessary matter, momentarily stopped by the workmen for examination, &c. without being able, on the instant, to modify the speed of the prime mover. Thus a great difficulty lies in the way of regulating the movement of the machinery, as the engineer is not able to see exactly the state of matters in the workshops, by which he could render assistance in altering his engine. Suppose that the labouring force of a certain number of looms should amount to 24 horse power, which will be reduced to 20 if three or four looms are stopped during a certain time represented by t. The labouring force of the resistance is thus reduced during this time in the ratio of $20 \times 75 \times t,^{km;}$ bearing in mind that a single horse power is represented by the elevation of 75 kilogrammes to a height of 1 metre in a second of time.

We shall consider that the labouring force of the prime mover is equal to 23 horses. The excess of the labouring force over that of the resistance is reduced by the interruption of the four looms to 23—20, or 3 horse power. This excess is repeated during t seconds, equivalent to $3 \times 75 \times t$; and we have, at the termination of the time, for the fly-wheel, a velocity V much greater than the velocity V, corresponding to the usual mode of operation of the machine. Then $\frac{P}{g}(V^2 - V_1{}^2)$ is the increment of the ***vis viva*** of the fly-wheel, equal to $2 \times 3 \times 75,\ t$. Thus we have $\frac{P}{g}(V^2 - V1\ ) = 2, 3, 75.\ t = 45^0\ t$; and, considering that the velocity V should not exceed that of V^1 more than $\frac{1}{10}$th, we have

$$V = \tfrac{11}{10}\ V_1, \text{ or } V^2 = 1.21.V_1{}^2, \text{ or}$$

$$\frac{P}{g} \times 0.21,\ V_1{}^2 = 45^0\ t, \text{ or } P\ V_1{}^2 = \frac{981 \times 450\ t}{21}$$

Spinning machinery is generally moved by steam engines, and to determine upon the fly-wheel for this latter, independently of the looms, let us suppose n to represent 30, so as to render the fly-wheel more powerful, according to the English system. Again, and which we think is the better speed, let us put 15 as the value of n, and calculate accordingly a fly-wheel to regulate a set of spinning machines. If the weight of this latter is much greater than the former, it is evident that n should be more than 15, and it becomes necessary to increase it; if it is less, it is obvious that we must take the former example.

SHORT READINGS IN ELECTRICITY.

BY MR. R. SMITH, BLACKFORD.

III.

In our two preceding papers, we have discussed the phenomena of attraction and repulsion—the law of induction, and entered into a practical view of the various instruments for producing, accumulating, and retaining electricity. In this, our third reading, we propose to commence a description of the apparatus employed for the purpose of indicating slight traces of the electrical fluid. Delicate, or feeble currents of electricity are immediately rendered evident by the application of an instrument, termed the electro-

meter, invented by Mr Bennett, and since considerably improved by Mr Singer. It consists of a plate of brass, having a cylinder of glass fixed upon its surface by means of cement. The top of the glass cylinder carries a brass cap, in the centre of which is fitted a small glass tube, coated both internally and externally with gum-lac. A wire is passed through the interior of the tube, carrying at its lower extremity two parallel slips of gold leaf. Dust or other extraneous matter is prevented from filling up the tube by a brass cap, fitted on the top; all the joinings are cemented so as to prevent a free communication between the interior of the tube and the external atmosphere, and the whole of the glass is also coated with gum-lac varnish. This apparatus is rendered still more delicate by connecting an insulated plate with the cap of the electrometer, and disposing a second one of the same size near it, connected with the earth by a brass pillar, jointed so as to allow of any alteration of distance between the two plates. In using the instrument, the plate attached to the pillar is brought as near as possible to the one connected with the electrometer cap, without absolutely touching it. In this state, it will detect the most feeble currents, the distance between the plates being increased when it is to be subjected to more powerful electricity. The electrometer thus fitted up with the metallic discs, is termed the condenser. Fig, 1, represents the apparatus complete. A, is the metallic stand, upon which, the glass cylinder B, containing the strips of gold leaf is fastened. C, is the cap, and D, the pillar and discs. If a stick of sealing-wax frictionally excited, is brought near the cap of the electrometer, the gold leaves will immediately diverge as represented in the cut; and the brass plate will become positively, and the gold leaves negatively electrified. If the plate A, is touched with the finger, the gold leaves will immediately approach each other, and will return to their normal state, but the cap will still remain positively electrified, owing to the proximity of the excited wax.

Coulomb's torsion electrometer is an elegant adaptation of the pith balls, to the discovery of minute quantities of electricity. Fig. 2, explains this arrangement. A, is a vessel of glass, bell-shaped, and resting on a stand. B, is a graduated scale surrounding the exterior of the glass vessel. C, is a glass tube fitted into the neck of the bell-glass, having at its upper end, a small circular plate of ivory, D. This plate is graduated round its circumference, and is fitted with a moveable index. A fine silk or glass thread is attached to the centre of the plate, passing down the tube C, into the bell-glass beneath, where it supports a slender needle balancing two pith balls. A hole is made through one side of the glass vessel, in order to admit a wire carrying a metallic ball at each extremity, as seen at F.

When an excited electric is brought near the outer ball F, it becomes electrified, as well as its neighbour in the interior of the

Fig. 1.

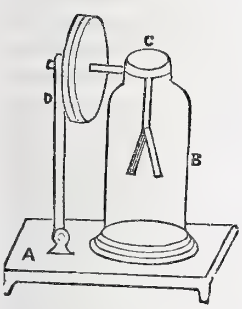


Fig. 2.

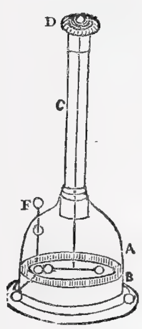


Fig. 3.

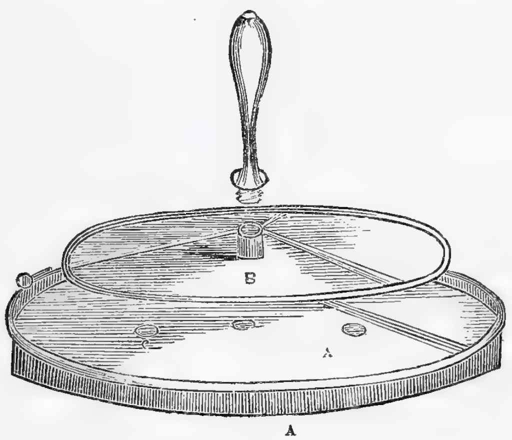
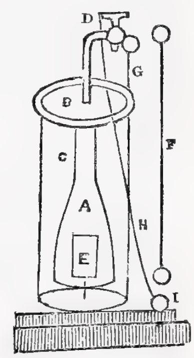


Fig. 4.



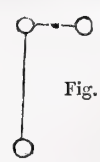


Fig. 5.

bell-glass, and the nearest pith-ball of the balanced needle is repelled, the distance which it moves measuring the intensity of the electricity operating upon it. By employing two gold leaf electrometers, a beautiful experiment, tending to show the electro-polar state of a conductor under induction, may be performed. The instruments are placed upon a table, at a distance of 16 or 18 inches from each other, and a wire laid across their caps. If an excited rod of glass is then brought near the cap of one of them, the gold leaves in both will diverge; then, if the wire is removed previous to disturbing the position of the glass rod, an examination of the instrument will show that the gold leaves in the one nearest the excited rod are negatively, while those in the other are positively electrified. If a second wire is now laid on the caps, by means of an insulating wax-handle, the leaves in both will immediately collapse, proving in the first place, that two diametrically opposite forces were given to the wire, and secondly, that these two opposing forces were of co-equal energy.

Professor Volta's electrophorus is sometimes employed instead of the common electrical machine, its action being illustrative of the principles of induction.

This instrument, which was invented in 1744, consists of a circular metallic plate surrounded by a rim, upon which a composition of Venice turpentine, rosin, and shell-lac is poured at melting heat, forming what is called the resinous cake and sole.

Fig. 3 is a perspective view of this instrument as modified by Mr Philips. A A, is the resinous cake and sole, constructed as before described; B, is the metal cover, provided with a glass-handle. When using it, the resinous surface of the bottom plate, is excited by friction with warm flannel, or, what is better, by striking it with a piece of cat's-skin; the cover B, is then placed on the resinous cake, and, by induction, the lower surface becomes *positively*, and the upper one *negatively* electric. Upon removing the cover by the insulating handle, it will be found to have acquired a very slight amount of *negative* electricity. If the cover is replaced, and is uninsulated by a touch of the finger, a small spark will make its appearance, and the electrical equilibrium of the upper surface will be restored. Let the cover be raised a second time, by its insulating handle, and it will produce a strong spark of *positive* electricity, which may be communicated to a Leyden phial in the usual manner.

The operation may be repeated to an unlimited extent, without re-exciting the resinous cake, as it loses nothing by its action, which is produced solely by its inductive influence on the combined electricities actually in the plate. If kept free from moisture, a spark may be obtained from it for weeks, which property has acquired for it the name of an electrical magazine; hence its illustrious inventor termed it *electrofero perpetuo.*

In the modification of the apparatus by Mr Philips, some additions are introduced for the purpose of affording a ready means of establishing a communication between the cover and the earth, without the troublesome process of touching with the finger, which is inconvenient when sparks in rapid succession are required. A narrow slip of tin-foil is placed across the surface of the resinous cake, and is attached at each end, to the metal rim. A second arrangement consists in attaching a brass ball by a wire to the edge of the resinous plate as seen; by this means, the communication may be rapidly made and broken with ease. Volta, also applied this instrument to the production of light. Fig. 4 represents a modification of this lamp, by the author of this paper. A, is a plain glass funnel, the narrow end of which is fixed in the centre of the wooden cover B, of the exterior cylindrical glass vessel C; a brass tube, fitted with a jet and a stop-cock D, is cemented into the upper orifice of the funnel A. E is a piece of zinc fastened upon a glass rod, and attached to the bottom of the glass jar C, and passing up into the wide part of the funnel A, the lower extremity of which approaches very nearly to the bottom of the jar. A brass rod F, having a ball attached at each end, is fastened to the wooden cover by a piece of insulating glass. G, is a second brass ball, also attached to the wooden cover by a brass wire; it is placed on a level with the upper ball on the rod F. A silk cord H, is attached at one end to the stop-cock, and at the other to a ball I, upon the electrophorus. The glass jar C, is filled with diluted sulphuric acid, and hydrogen gas being disengaged by the action of the acid upon the zinc, decomposing the water, it is expelled by the weight of the fluid column, through the jet tube. So soon as the atmospheric air is expelled from the tube, the stop-cock is closed, and the consequent accumulation of gas forces the fluid out of the funnel into the jar, until it is below the level of the zinc, when the action will cease. The silk cord H, is now to be attached, and if the stop-cock is opened, the ball upon the cover of the electrophorus will be raised up to the ball of the brass rod, and a spark will pass along the brass rod to the upper ball, and thence to the ball opposite, and in its passage will inflame the hydrogen arising from the jet tube. A pointed wire is fixed on each ball to direct the spark through the hydrogen, as represented in the detached view of the balls fig. 5.

ON THE CONSTRUCTION OF ORGANS.

Before entering into a description of the mechanical construction of the Organ—which, from the grandeur of its tones, the beauty of its mechanism, and its unlimited capabilities, has been justly styled the "King of Instruments," we will take a cursory glance at its history in this country, from the period of its introduction into our churches, until the present day. At the same time we may offer a few practical remarks upon the respective merits of the English and German methods of organ building, concerning which so much discussion has lately arisen. It was not until the reign of Henry VIII. that the organ began to assume any thing of its present shape. The semi-tones were then introduced and the compass extended to four octaves. The organ of this period comprised two manuals, the one a choir or soft organ, and the other the great or loud organ. The former generally contained a stopt Diapason, Principal and Flute, and the latter, two open Diapasons, stopt Diapason, Principal, Twelfth, Fifteenth and Twenty-second; hence the instruments of this period are termed in old writings, "a pair of organs." This is the first intimation we find of the existence of harmonic stops, namely, those speaking in fifths and thirds to the unison, which now form so prominent a feature in the Grand Organ, and of which we shall speak more fully hereafter. As we find no mention made of Reed stops or those of the Trumpet kind, we conclude they were not then invented. From the above period until the reign of Charles I. very little progress appears to have been made in the art, and in the revolution which followed, the instruments found in the Cathedrals and Churches were doomed to speedy destruction by the Parliamentary army. After the battle of Worcester an old historian remarks, that the children in the streets of that city were seen using as whistles the pipes of the Cathedral organ, which, together with the whole edifice itself, had been despoiled and mutilated by the fanatical soldiery of Cromwell. In consequence of these proceedings, the art, as might be expected, rapidly went to decay, for we find that at the Restoration, so great was the dearth of organ builders, that the King, (Charles II.) was compelled to offer a premium as an inducement to foreign artists to come over and settle in this country. The result was the arrival of Bernard Schmidt and Harris, natives of Germany and France; Schmidt was immediately employed in erecting an organ for the Chapel Royal at Whitehall, and subsequently in his celebrated contest with Harris at the Temple Church, his reputation as a builder was established, his instrument having been unanimously declared superior to that of his rival. After this decision public patronage was liberally bestowed upon Schmidt, as the various organs of his construction to be found in our cathedrals and churches will abundantly testify. These organs are distinguished by a great weight and solidity in the Diapasons, and a correct arrangement of the mixture or harmonic stops, but the reed stops are very inferior. Although we do not coincide with those enthusiastic individuals who consider Schmidt the model of organ builders, and whom we have heard gravely state that the art of producing what they term "the fine old tone" is lost for ever, we are nevertheless willing to admit that there is a boldness and vigour in the tone of his organs (the one in the Temple church particularly) which certainly ought to put to shame the attempts of some of our modern builders. The real secret of Schmidt's "voicing" was, that he gave the pipe its full allowance of wind, and regulated the pressure upon the bellows with discretion, by which means although his "voicing" was coarse and his pipes ill made, he managed to produce a breadth and symmetry of tone in the *ensemble* which is infinitely preferable to the thin and weak tone of Suetzler, Green and Avery, who lived a century afterwards. Although Harris was defeated in his competition with Schmidt for the Temple organ, he built several (for the time) good instruments, of which the most favourable specimen is the one in Doncaster church. In his reed stops he excelled his contemporary, and his general tone, if not possessing the body of Schmidt's, was very brilliant and pleasing. From the above period until the last few years, extraordinary though it appear, no progress had been made in the art, with the exception of the invention of the "Swell" by Crang, about 1760, which was merely the addition of another manual organ. This was enclosed in a box, having a door opening and shutting with a pedal to give the effect of the "Crescendo," and "Diminuendo." Our builders continued erecting organs upon the same plan as their predecessors had followed a century and a half before, and the slightest departure from the rules they had inherited from their forefathers, was looked upon by them and the organists as little short of heresy.

Fortunately the introduction of the works of Bach and other composers of the German school has done a great deal to remedy this state of things. It was found that the great contrapuntal writings of that great master, could not be interpreted upon the English organ; this naturally led to a comparison between our method of construction and that adopted by the Germans, and the result proved that while the latter had studied and perfected the art, we had totally neglected it. The principal feature in the German instrument is an overpowering weight and grandeur of tone upon each individual key, and to effect this great desideratum their builders wisely departed from the custom invariably followed by our countrymen, namely, that of making the *unison* the fundamental sound upon which to build their harmonic stops and mixtures, and instead of which, they formed the bold design of adding the "Tenoroon Diapason," one octave below, and even the "Untersatz," which is two octaves below the unison. They then added the harmonics derived from those stops, namely, the "Quint," or twelfth above the Tenoroon, and the "Decima," or seventeenth above that stop. Having thus laid such a solid foundation, their smaller stops could be added to an almost unlimited extent, giving brilliancy and elasticity to the whole, whereas in an English organ not possessing these fundamental stops, the effect would be squally and thin. Hence the performer, instead of grasping at as many notes as he could possibly hold down with both hands, (not forgetting a full chord or two in the bass), as was the practice of our organists, can give a greater effect by merely playing in four parts.

Bach was fully aware of this when he wrote his masterly preludes and Fugues, for we rarely see more than four or five notes in the manual and one in the pedal, written to be played at once. We will here shortly describe the harmonic stops, namely, Quints, Decimas, Twelfths, Tierces, and mixtures. It may appear extraordinary to the casual observer that there should be stops introduced into the organ, which should speak in consecutive thirds and fifths to the fundamental sound; for instance, supposing a note is held upon the full organ, say C, we not only have the note C, but also the notes E and G above, and their octaves above again, and so on in perfect major chords. One would imagine, therefore, that in holding down four notes, namely, C, E, G, C, each note having its distinct major thirds and fifths, that the effect produced would be an unintelligible discord. The contrary however is the case. The only way of solving this apparent anomaly is the fact that every single sound in nature is accompanied in a greater or lesser degree by its harmonics, namely, its twelfth and seventeenth, and in a bell even the twenty-first is perceptible. The organ-builder, therefore, by adding to and strengthening these harmonic sounds produces that grandeur of effect for which the organ stands unrivalled. The compass of the German organ is from C below the bass clef to F in alt 54 notes, and the pedal is from C C C to C, two octaves. The lowest pipe in the pedal organ is usually C C C C, 32 feet long. The compass of the English organ is from G G to F, 59 notes, with no pedal organ. The lowest pipe is G G 10 feet long. It will be seen by the foregoing remarks, that unless an organ, particularly a large one, is built upon a correct plan, no matter how fine or exquisite the workmanship may be in its details, a perfect failure must be the result; and yet we see some of our first professors adhering tenaciously to the old system with a perseverance worthy of a better cause.

We have a lamentable instance of this in one of our corporate towns, where, after a liberal sum having been voted by the Town Council for the erection of an organ, which might be ranked equal to those at Haarlem and St. Denis, the arrangement and superintendence of it is entrusted to a professor totally incompetent for the task; one who views what he is pleased to term "modern innovations," with abhorrence. The result must inevitably be his signal disgrace.

We will now attempt to describe the interior mechanism of the organ in a manner that may be intelligible to the general reader, and in so doing we will avoid technicalities as much as possible, although to enter into a minute and comprehensive detail, we should require the aid of plates sufficient to fill a large volume. The Grand organ in the Town Hall, Birmingham, shall be our example. This instrument was built by Mr Hill of London, (to whom belongs the merit of having introduced the German system into this country) in 1832, at a cost of £3500. In 1843 it was remodelled upon the new plan, and it may now be ranked among the finest organs in Europe. The first thing to be noticed is the "Bellows" which consists of a "Top Board," "Middle Board," and "Feeders." The "Top board" is attached to the "Middle board" by means of "ribs" which are formed of wood half an inch thick and jointed together by means of leather, so that they will fold up or expand as the top board is raised or depressed. On the underside of the middle board are placed the feeders, which have their "ribs" similar to the middle and top boards. In the feeders are cut holes, over which, in the inside or upperside are placed valves. In the middle board, directly over the feeders, are also holes and valves which open upwards, thereby preventing the air when ejected from the feeders, from returning. Supposing the bellows at work, the blower by means of handles and levers lets down the feeders, the air consequently rushes into the cavity between the feeders and the middle board, (the sides being perfectly air tight) through the valves, which immediately shut, upon the feeder being again raised. The air therefore finding no outlet by the valves through which it entered, forces up the valves in the middle board and enters the space between it and the top board where it remains until used. This space is called the reservoir, it being the common receptacle into which the air from the feeders is thrown. On the top of the top board which rises as the air is thrown in beneath, are placed weights to give the necessary pressure of wind. In the Birmingham Organ the feeders of the Great bellows are placed in a room forty feet from the reservoirs, with which they communicate by means of hollow trunks. There are in the above organ 4 reservoirs and 7 feeders. The feeders are so arranged that the blower raises the larger while he depresses the smaller ones, the lever having a double action, thus a constant supply of wind is obtained. The German method of blowing is very defective. They have recourse to a great number of small reservoirs similar in size to common forge bellows. They are placed in a row, and by means of treadles the top of each is raised in succession and allowed to fall as the air they contain is exhausted. In consequence of the great number of these small bellows, and the rapidity with which they are exhausted, the labour of blowing is immense, it often requiring six stout men to keep up the supply for the full organ, whereas in the Birmingham one, more can be supplied by three. Having explained the Bellows, we will proceed to the "Sound Board" which is a rectangular box divided in the interior into channels or "grooves" which correspond with the number of keys of the organ. On the upper side of the sound board are the "slides" and "upper boards." Holes are bored through these into the grooves, and in these holes are inserted the pipes. The slides are thin narrow pieces of wood corresponding with the stops of the organ, so that being moved lengthwise by a person drawing the stop, the holes in the slide are drawn over the corresponding holes in the grooves and upper boards, and the communication is consequently open between the grooves and the pipes. If the stop is pushed in, the slide assumes a different position and the communication is cut off. On the under side of the grooves are placed the "pallets" or valves which admit the wind into the grooves.

The surface of the groove is here covered with leather, with the exception of a small aperture about ten inches long, and the whole width of the groove, which varies from $\frac{1}{4}$ of an inch in the treble to $1\frac{1}{2}$ inch in the bass. Covering this aperture is the pallet, a long narrow piece covered with leather so that it will fit closely to the aperture. One end of this leather forms a hinge which, by allowing the other end to be drawn down, keeps it in its proper position. Under the pallet is placed a spring by which it is pressed closely over the aperture. Enclosing the pallets is a box into which the wind is admitted by means of a "wind trunk" from the reservoir of the bellows. The pallets have wires attached to them passing through the box enclosing them, and by sundry movements are attached to the keys by which they are governed. Supposing a person wishes to play, he first draws out the stops he intends using, by which means the slides open the communication between the pipes and grooves, he then presses down the keys which being attached to the pallets, causes them to open; the wind therefore rushes through the aperture into the grooves and then through the slides that are drawn, and through the upper boards into the pipes. When the finger is removed from the keys, the spring presses the pallet back against the aperture and the communication is stopped. The "Trackers" are long thin slips of wood which form the connecting medium between the keys and pallets. In the Birmingham organ the trackers, if laid out in a straight line, would reach four miles. The intermediate movements which connect the keys with the corresponding pallets, inside the organ, are the "Squares" and the "Roller boards." The squares are right angled levers and are used to direct the horizontal movement into a vertical one; for instance, the keys of the Birmingham organ are placed at a distance of twenty feet in front of the instrument, and to effect a communication between them and the pallets, the squares and roller boards are put into requisition. The key is a common lever having a fulcrum in the centre. On the extremity of the key lies one arm of the square; the other arm, being at a right angle with the one on the key, points downwards, so that it necessarily follows that when one arm is raised by means of the key, the other is drawn forward, thus giving the horizontal motion to the tracker, which is fixed to the arm by means of a wire hook. At the other end of this horizontal tracker is also fixed a square frame by which means the motion is again directed from the horizontal to the vertical until it reaches the roller board. The roller board consists of a frame upon which a number of wooden rods or rollers are placed. Inserted in the face of these rollers at each end, are iron arms having holes drilled at their ends. The trackers from below after having passed the various squares are affixed to the arms at one end of the rollers, by means of a wire hook inserted in the hole. The arms at the other end of the rollers are placed under the pallets which they govern, and are attached to them by means of other trackers and hooks, so that when one end of the roller is drawn down by the tracker from below, the other is drawn down at the same time, and with it the pallet. The roller board in fact serves to condense and bring together the action from the sound boards (which necessarily occupy a great space) into the narrow compass of the key board. It should be borne in mind that the connection between the keys, squares, roller boards, and pallets, is always by means of trackers, which by their extreme lightness are admirably calculated for the purpose. In the Birmingham organ, the trackers of the swell organ after passing in a horizontal direction for twenty feet, ascend to a height of forty feet before they reach the pallet, and still the touch is perfectly light and easy.

In consequence of the pipes in the organ before mentioned having been constructed on a scale hitherto unattempted, the common pallet was found inadequate to give them a full supply of wind. The resistance of the compressed air upon such a large surface of pallet as would be required, to give the necessary supply, was found to be so great that the weight and stiffness of the touch could not be overcome by the organist. To correct this difficulty a valve was invented by Mr Hill for which he was presented with a silver medal by the Society of Arts.

The peculiarity of this valve is, that the pressure instead of being directly against the finger of the performer, is directed against a centre, so that he has merely the friction of the centre to overcome, which is comparatively trifling. The large pipes by this means can be played by the finger with perfect ease.

As we find we are exceeding our limits, we will briefly describe the pipes of an organ, and also add a list and explanation of the stops of the Birmingham organ with which we must close. The pipes are divided into three classes, the wood, the metal, and the reeds. The wood pipes are long tubes having a mouth at bottom by which the note is produced. Below the mouth is a chamber into which the wind is introduced. From that chamber it escapes by a narrow aperture the whole width of the pipe. This aperture is immediately under the mouth of the pipe, so that the wind by striking against it, sets the air in the pipe in motion and produces the note. These pipes range in the Birmingham organ as low as C C C C, which is 32 feet long and three feet in diameter. Another description of wood pipes are those called Stopt Diapasons, which instead of being open at top, have a moveable plug inserted, capable of shifting up or down for the purpose of tuning. These pipes produce a note one octave lower than the open ones; for instance a stopt pipe of 8 feet will produce the same note as an open one of 16 feet although the tone is much weaker in the former and has a great predominance of the harmonic twelfth. The metal pipes are circular tubes which are shaped at bottom like an inverted cone, termed the foot. Between the foot and the body of the pipe is a partition. The foot and the body are both flattened for a short distance up the pipe so as to form the mouth, and the air escapes through an aperture between the partition (which is cut to fit the flattened surface) and the foot of the pipe, and by rushing into the hole or mouth, vibrates the air in the pipe and produces the note. These pipes range in the Birmingham organ from C C C C 32 feet, to F, $\frac{3}{4}$ of an inch long. The largest pipe stands in the front tower of the case and is 22 inches in diameter.

The reed stops are conical pipes, wide at the top end and going off to a narrow point at bottom. The top or main body of the pipe termed the "tube," is inserted in a block having a hole perforated in it, into which on the under side is inserted the reed. The reed is a brass tube closed at bottom, and having an opening lengthwise from top to bottom. Upon this opening, the edges of which are smoothed to a flat surface, is placed the "tongue," which is a thin slip of brass having a slight curve, so that it is fixed by a wedge close to the reed at top, leaving the bottom a short distance from it. The whole, namely, the block, reed, and tongue, is inserted into a tube termed the socket, at the bottom of which the wind enters, setting the tongue in motion. These vibrations are communicated through the hole in the block to the air in the pipe, thus producing the note. The largest of these pipes in the organ before mentioned is C C C C, 32 feet long, and the diameter at top 12 inches. The tongue or vibrating medium of this pipe is 9 inches long and $\frac{1}{10}$th of an inch thick. These pipes are tuned by means of a spring which presses upon the tongue near the top. This spring being moveable is raised or depressed by the tuner, by which means the vibrating portion of the tongue is lengthened or shortened, the former flattening and the latter sharpening the pipe.

The stops Pasaune, Trumpet, Clarion, Cremona, Oboe, Cornopean, &c. are constructed upon the above principle. A new reed stop, invented by Mr Hill, has been placed in the Birmingham

organ. It is termed the "Tuba Mirabilis," a very appropriate title considering its wonderful power and body of tone. This stop has a separate bellows with a pressure of twelve inches of water; the pressure is regulated by means of a common glass guage as employed in blast furnaces, &c. The Tuba Mirabilis has been introduced latterly by Mr. Hill, into the organ at York Minster, which instrument was erected by him in 1827.

It may now be necessary to explain the relations which the respective stops bear to the unison, in order that our readers may perceive the great amount of harmony produced upon a single key of the Grand organ. The open Diapason is the unison or predominant sound, the lowest note C, (on the German organ) is 8 feet. The Tenoroon Diapason, is one octave below the unison. The principal is one-8th above the unison. The Quint is one-5th above the unison. The Decima, the Twelfth, and Fifteenth, are, as their names imply, a 10th, 12th, and 15th above the unison. The Doublette is of two ranks of pipes composed of a 15th and 22nd above the unison. The Sesquialtras, Mixtures and Fournitures are composed of from 3 to 5 ranks of pipes, and contain the 17th, 19th, 22nd, 24th, 26th, and 29th above the unison. The Reed stops are Contra, Trumpet, *k* octave below the unison. Pasaune, Trumpet, Oboe, Cremona, Unisons, Clarion, one-8th above the unison, and octave Clarion 15th above the unison. It must be borne in mind that the unison of the manual is 8 feet, and that of the pedal 16 feet in the lowest note.

Description of the Birmingham Organ.

Grand Organ, C to F
54 Notes.

Stop		Feet.
Tenoroon Diapason,	-	16
Open Diapason, 1,	-	8
Open Diapason, 2,	-	8
Open Diapason, 3,	-	8
Stopt Diapason,	-	4
Quint,	- - -	5
Principal, 1,	- -	4
Principal, 2,	- -	4
Twelfth,	- - -	2½
Fifteenth,	- -	2
Doublette,	2 ranks,	21
Sesquialtra,	5 ranks,	—
Mixture,	3 Do.	—
Fourniture,	5 Do.	—
Reeds: Contra Trumpet,		16
Reeds: Pasaune,	-	8
Reeds: Clarion,	-	4
Reeds: Octave Clarion,		2

Pedal Organ, C C C to F,
30 Notes.

Stop		Feet.
Open Wood,	- -	32
Open Metal,	- -	32
Open Diapason,	-	16
Open Diapason,	-	16
Open Diapason,	-	16
Sub Bass,	- - -	8
Principal, 1,	- -	8
Principal, 2,	- -	8
Twelfth,	- - -	5
Fifteenth,	- -	4
Sesquialtra,	5 ranks	—
Mixture,	3 Do.	—
Reeds: Grand Trombone,		32
Reeds: Pasaune,	-	16
Reeds: Clarion,	-	8
Reeds: Octave Clarion,		4

Swell Organ, 54 *Notes*.

Stop		Feet
Tenoroon Diapason (Stopt Bass),	- - -	8
Open Diapason,	- -	8
Stopt Diapason,	-	4
Principal,	- -	4
Fifteenth,	- - -	2
Sesquialtra,	-	3 ranks
Flageolet,	- -	4
Horn,	- - -	8
Trumpet,	- -	8
Oboe,	- - -	8
Clarion,	- - -	4
Tuba Mirabilis,	- -	—

Choir Organ, 54 *Notes*.

Stop		Feet
Open Diapason,	-	8
Stopt Diapason,	-	4
Principal,	- -	4
Fifteenth,	- -	2
Hohl Flute,	- -	8
Oboe Flute,	- -	4
Wald Flute,	- -	4
Harmonica,	- -	4
Cornopean,	- -	8
Cremona,	- -	8
Bassoon,	- - -	8

In closing our imperfect description of the noblest of instruments, we trust we have succeeded in giving our readers a general idea of the peculiarities of its construction, and we cordially hope before long to see it more generally introduced into our public Halls and Mechanics' Institutions, where the intellectual gratification it affords may be appreciated and enjoyed by the many. That music has a tendency to elevate the taste and humanize the mind is now universally acknowledged; and its more general cultivation on the continent than in this country has probably contributed, in no small degree, to diminish the evils of intemperance.

ON THE PREVENTION OF THE OXIDATION OF IRON.

Several improvements have lately been made in the important process for the prevention of the injurious effects of oxidation upon iron, a subject which has long attracted the attention of scientific men.

One of these methods, consists in the addition to pig iron, when in a state of fusion, of from 2 to 10 per cent of copper, tin, nickel, or antimony, by which addition, the iron is rendered more malleable and less subject to oxidation. A second method consists in imparting to the iron a coating of steel, or rather a species of iron containing less carbon and of course approaching to steel. This is effected by the addition of one part of blister steel to four parts of molten cast iron, and then adding scrap iron to the mass, until an iron rod is no longer rendered brittle by being dipped in the mixture. With this compound, common iron is coated in the same manner as pursued in the case of covering iron with brass; but various methods are adopted, according to the size and nature of the article to be coated. Where it is at the end of a bar of iron, such as an axle, and is to be of a particular form, this form may be given to the crucible, thereby making it a mould, and when in a state of perfect fusion, the iron, either previously heated or cold, is to be immersed in the melted mass, and when it is perceived that the mass is perfectly fluid, then the fire may be withdrawn, or the crucible be allowed to cool by any available means.

When the iron to be coated is immersed cold, the melted mass is immediately congealed, but it must be permitted to remain in the crucible till it again becomes fluid, and then it should be allowed to cool. If the whole is allowed to cool slowly, it is then soft, and may be turned in the lathe, and afterwards hardened by heating it and cooling it suddenly in the usual manner; but in this case care must be taken, as the coating and the iron have different powers of contracting. If the coated parts were suddenly immersed in water, it would certainly crack; the uncoated part must therefore be immersed up to the coated part, when the conducting power of the iron will cool the coating sufficiently quick to ensure a proper hardness.

A third method of preventing oxidation, is by case hardening the metal, by the use of the ferrocyanide of sodium, calcium, or barium.

In order to apply the ferrocyanide, an alkaline bath, formed with carbonate of soda, or other alkali, is used. This bath may be a crucible or large basin built in the brickwork of the furnace, which should be a reverberatory furnace, and previous to being used, should be raised to a white heat; the iron to be case-hardened requires to be previously heated to nearly a red-heat, and then immersed in the bath, and there raised to a heat sufficiently high, after which it must be immediately immersed in the ferro-cyanide previously fused in another vessel; but if the quantity of iron to be case-hardened is small, it would not be advisable to fuse the ferrocyanide (as it is very soon decomposed), but immediately on taking it out of the bath it must be sprinkled with the ferrocyanide; should ferrocyanide of potassium be used, it is found that the alkaline bath prevents effectively the corroding of the iron.

A fourth scheme consists of a method of coating copper, or the alloys of copper or iron, with platinum. Platinum is dissolved in aqua regia, and the iridium which remains undissolved as a black powder, separated by filtration, then evaporated to dryness, and when cold a quantity of caustic potass, equal in weight to the metallic platinum employed is to be dissolved in water, and poured on the chloride of platinum. This will precipitate the platinum of an impure yellow colour; a quantity of solution of oxalic acid equal to the weight of the metallic platinum, is now to be added without pouring off the solution which remains on the precipitate; the solution is then to be boiled till the precipitate is entirely dissolved; a small quantity of iridium will still remain, which, together with any other impurities, must be separated by filtration; caustic potass equal to twice the weight of the metallic platinum is to be dissolved in water, and added to the above. The solution is now ready for platinising the copper or iron article which is to be coated with platinum. The article to be coated is to be put in a vessel of glass, or earthenware, and the above solution is to be poured in, sufficient to cover it; let it then be connected with the positive pole of a Daniel's or Bunsen's battery of one or more pairs of plates, according to the size of the article to be coated, and a piece of platinum foil in connection with the negative pole is to be immersed in the solution. The deposition of the platinum in a metallic state

on the surface of the metal article immediately commences, and may be continued till the required thickness is obtained.

Scientifically speaking, we see no objection to any of these methods, as regards the effectual result of their application, but looking at the matter commercially, the simple question naturally suggests itself—will it pay? will not the cost of adding from "two to ten per cent. of copper" swallow up the supposed gain in point of freedom from oxidation?

IMPROVED LEVELLING BOOKS AND LEVELLING STAFF.

The following specimen of a "Levelling Book," which has also columns for gradients, cuttings, and embankments, is submitted by Mr. Lister, Engineer, as an improvement upon the usual method.

The whole particulars occupy two pages: on the left-hand page are entered the columns for—1. Sights; 2. Rise; 3. Fall; 4. Levels; 5. Distances, and 6. Gradients; and on the right-hand page is entered one column for Cutting and Banking, and the remainder of the page is for Remarks.

The 1st column contains the readings from the levelling staff, the first reading A being entered on the left, and the other readings on the right hand of the column to facilitate the checking of the work, ascertaining the difference of the first and last sights.

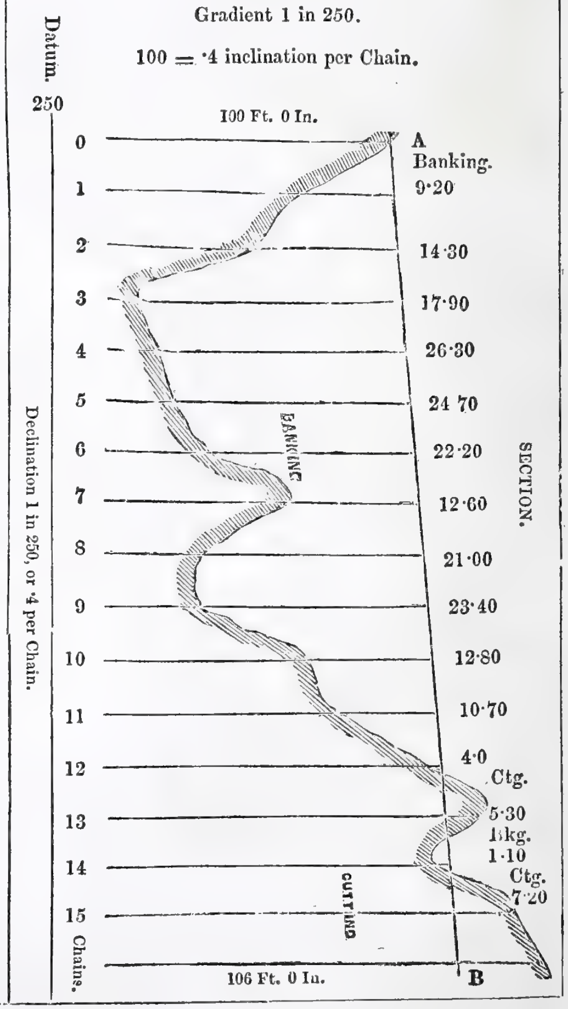
1 Sights.	2 Rise	3 Fall.	4 Levels.	5 Distance.	6 Gradient.	7 Cutting & Banking.
1·20 A	+	—	100·00	Feet. 0 A	100·00 + 40	B
× 10·00		8·80	91·20	100	100·40	9·20
14·70		4·70	86·50	200	100·80	14·30
0·40						
13·60		13·20	73·30	300	101·20	27·90
7·00						
5·00	2·00		75·30	400	101·60	36·30
× 3·00	2·00		77·30	500	102·00	24·70
0·10	2·90		80·20	600	102·40	22·20
14·00						
4·00	10·00		90·20	700	102·80	12·60
12·00		8·00	82·20	800	103·20	21·00
× 14·00		2·00	80·20	900	103·60	23·40
3·00	11·00		91·20	1000	104·00	12·80
0·50	2·50		93·70	1100	104·40	10·70
13·00						
× 6·00	7·00		100·70	1200	104·80	4·10
12·80						
3·00	9·80		110·50	1300	105·20	Ctg. 5·30
× 9·00		6·00	104·50	1400	105·60	Bkg. 1·10
B 0·30	8·70		113·20	1500	106·00	Ctg. 7·20

REMARKS.

Datum 100 Feet below A. Chain 100 Feet.

Gradient 1 in 250.

100 = ·4 inclination per Chain.



Vertical Scale, 30 ft. = 1 in.

After every last sight is entered, and before the level be removed, a mark is drawn across the column, and after the level is again fixed, the first sight is to be entered on the left as before. The × denotes the position of the level, which should always be placed as near midway as possible between each station. The columns Rise and Fall will be + or — according as the datum line is above or below.

The 4th and 5th columns require no explanation. The 6th column contains the Gradient per Chain, added or subtracted according as the gradient be ascending or descending; and the 7th column contains the differences between the 6th and the 4th columns, which gives the depth of cutting and the height of embanking. By the addition of these two columns the work is complete, and can be referred to at any time without referring to the section, which is sometimes very inconvenient.

In reducing the levels, take the difference of the sights succes-

sively, and enter in the second or third column, as the case may be. Prove the work as it is proceeded with, by taking the difference of the first and last sight between each station.

$$\left.\begin{array}{ll} \text{Namely,} & 1{\cdot}20 - 17{\cdot}70 = 13{\cdot}50 \\ \text{3rd Column,} & 8{\cdot}80 + 4{\cdot}70 = 13{\cdot}50 \\ \text{4th Column,} & 100{\cdot}00 - 86{\cdot}50 = 13{\cdot}50 \end{array}\right\} \text{All being equal is proof of the work.}$$

Again, from the 4th to the 5th station,

$$\left.\begin{array}{ll} \text{1st Column,} & 14{\cdot}00 - 0{\cdot}50 = 13{\cdot}50 \\ \left.\begin{array}{ll} \text{2nd Column,} & 10{\cdot}00 + 11{\cdot}00 + 2{\cdot}50 = 23{\cdot}50 \\ \text{3rd Column,} & 8{\cdot}00 + 2{\cdot}00 = 10{\cdot}00 \end{array}\right\} 13{,}50 & \\ \text{4th Column,} & 80{\cdot}20 - 93{\cdot}70 = 13{\cdot}50 \end{array}\right\}$$

Correct, and so on throughout.

Again, the difference of the sum of the first sights and last sights should be equal to the difference of the second and third columns, and also to the difference of the first and last entries in the fourth column; thus,

First Sight.	Last Sight.	2nd Col.	3rd Col.	4th Col.
1·20	14·70	2·00	8·80	100·00
0·40	13·60	2·00	4·70	113·20
7·00	0·10	2·90	13·20	——
14·00	0·50	10·00	8·00	13·20 difference.
13·00	6·00	11·00	2·00	
12·80	0·30	2·50	6·00	
——	——	7·00	——	
48·40	35·20	9·80	42·70	
35·20		8·70		
——		——		
13·20 difference.		55·90		
		42·70		
		——		
		13·20		

To those who are commencing the interesting practice of levelling, these suggestions may possibly be of some service, as may also be the following—

Simple Method of Levelling, and of Registering and Reducing the Levels to the Section in the Field Book.

Stations.	Rise.	Sights.	Fall.	Reduced Levels.	Distance in yards.	
1		5·26		100·00		Quay Wall above Datum.
2		3·20	2·06	97·94	5	Road.
		2·47				
	2·25	4·72		100·19	200	Rope Walk.
3	·60	5·32			230	Cap and Drain.
		1·45				
	3·05	4·50		103·84	400	Meadow.
4		2·65	1·85	101·99	570	Gatestead.
		7·65				
		4·85	2·80	99·19	600	Road.
		1·10	3·75	95·44	650	Meadow.
	2·00	3·10		97·44	..	
	2·82	5·92		100·26		
5	3·53	9·45		103·79	690	Cap and Farm.
					760	Meadow.
		4·72				
6	·02	4·74		103·81	780	Meadow.
		11·47				
7		2·21	9·26	94·55		Meadow.
		8·67				
8		4·34	4·33	90·22	800	Centre of Railway and Top of Rails.
		1·71				
9	10·94	12·65		101·16		
		2·30				
10	2·64	4·94		103·80	850	Meadow west of Railway.
	27·85		24·05			

27·85 — 24·05 = 3·80.

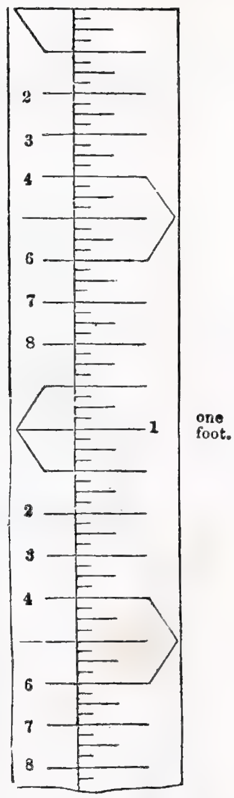
Proof. 49·50, sum of the *last* Fore Sights.
45·70, sum of the *first* Back Sights.

3·80

The difference of the Rise and Fall Columns is 3·80.
The difference of the last Fore and first Back Sights is 3·80.
And the last Sum in the Reduced Levels is 3·80.

Hence the accuracy of the work

The annexed figure represents a portion of the Levelling Staff used by Mr. Lister. It is made of clean light deal, in one length of 15 or 18 feet, graduated on both sides into feet, 10ths of feet, and 20ths of feet; 4 inches broad, and ½ inch thick. If so divided, it will be read off with greater facility and with as much accuracy as if divided into hundredths of a foot. It is shod with iron or brass. It is painted on both sides:—a black ground with white graduations and figures, on one side; and a white ground with black graduations and figures, on the other side. This variety is useful, as a black ground can sometimes be read off when a white one cannot, and *vice versa.* The marks should be cut in, and rather heavy than otherwise. The staff when painted, ought to be finished with three coats of the best varnish. The figures denoting the tenths should not be of the same kind as those denoting the feet; and, for the sake of further distinctness, the feet ought to be marked towards one edge of the staff, and the inferior graduations towards the other edge.



The annexed form of the field-book will explain itself. The *datum line* is below the section surveyed, hence the *fall* is substracted and the *rise* added in the *reduced levels.* When the datum line is above, the operation must be reversed.

Fix the spirit-level as nearly midway as possible between each station, then the curvature of the earth and refraction need not be noticed. Be accurate in entering the reading off of the staff. First take the reading, then enter it; then take the reading again to see that it is right. The greatest accuracy must be observed in taking the first back-sight, and the last fore-sight; and the staff must not be altered in the least, except turning it round, if it be not marked on both sides, until the spirit level be again fixed, and the first back-sight be taken, and so on through the whole line of section. It is well not to take very long sights.

REMARKS AND SUGGESTIONS ON HIGH PRESSURE STEAM GUAGES.

By R. Rawlinson C. E., Manchester.

In using high-pressure steam, it is of the first consequence that every boiler or steam-generator should have, if possible, an unerring and self-registering steam-guage; difficult to disorder, and impossible to be tampered with. Springs or levers, attached to safety-valves, are notoriously deficient in the above named requisites: and thermometers, where mercury is used, are soon destroyed by the heat to which they are subjected. To obviate these defects, I think a pyrometer might be constructed to measure and register the heat *in the boiler;* and, consequently, be an indicator of the pressure.

For this purpose, the difference in expansibility betwixt iron and brass may be brought into use:—Let there be either a cast or a wrought iron plate, or bar, fixed on the inside of any steam boiler, and a brass rod, of sufficient strength to prevent its bending, securely attached to the extreme inner end of the iron plate or bar; and let the other end of the brass rod be brought to the

outside of the boiler, through a stuffing-box, and there be connected with an indicator, which may be placed within a case, or box, having a glass plate over it, so as to allow the engine-driver to examine it; if the indicated pressure exceeds what is allowed, he can regulate the ordinary safety-valves accordingly. Thus, in case of accident, all excuse as to valves being out of order, and gagging, would be done away with. But, such an apparatus, without the indicator, may be placed *under a safety valve,* so that if the heat becomes too great in the boiler, the valve will be lifted by the brass rod, even though it should be very materially disarranged or overloaded; and, until the heat is reduced, the valve could not be brought down upon its seat again.

I have not given diagrams, as I feel sure the proposed instrument will be immediately understood by practical engineers; and, there may be many ways of applying the power gained by the increased expansion of one metal over another. One thing will be absolutely necessary, that the iron plate, or rod, or case, to which the brass is attached, be connected with the boiler by the opposite end only, so as to allow the instrument to be projected freely into the water, or steam, or both.

A good and safe steam-indicator and pressure regulator is an instrument that remains to be made, and the great increase of locomotive boilers is, of itself, a powerful inducement to invent and adopt some certain means of safety.

DUNN'S IMPROVED RAILWAY TURN-TABLES.

Most railway travellers have felt the disagreeable jarring which takes place from the passing of trains over loose turn-tables, which, indeed, form one serious drawback to the pleasures of railway travelling, to say nothing of the positive injury to the rails and carriages which must arise from this very common evil. The cause of this failing obviously lies in the faulty construction of the

Fig. 1.

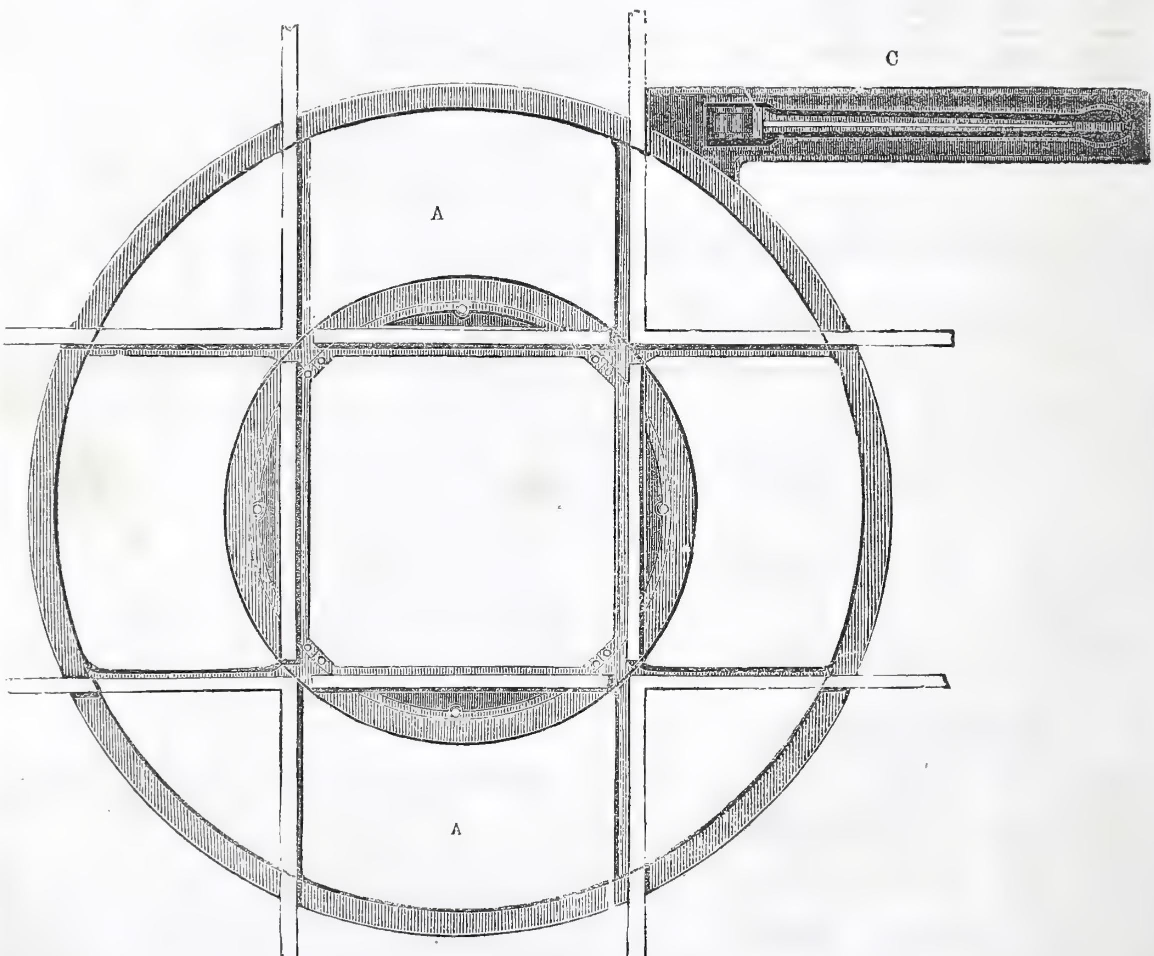
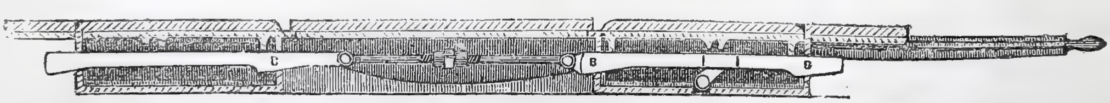


Fig. 2.



tables, of which there are many varieties, but all are beset with the self-same objections. The most general mode of construction is that in which the circular table turns upon a central pillar working in a deep socket fixed in the foundation, the rim of the table being further supported by a series of wheels revolving in bushes attached at intervals to the foundation: so that when a weight, as a

carriage, is suddenly brought upon one side of the table, any slight inequality in the supporting wheels causes the contrary side of the platform to be alternately raised and depressed, producing the objectionable jarring so much complained of.

In Mr. Dunn's turn-tables this is obviated by means of an arrangement of wedges, whereby the platform is disengaged, as it were, from its supporting rollers, and is steadied in a position perfectly level with the rails.

Fig. 1 is ground plan of an improved main line turn-table, and fig. 2 is a vertical section, showing the supporting wedges, the rollers being supposed to be removed.

The top plate A is in this case cast of an annular form, the ways for the carriage wheels being formed by casting grooves along the surface in which the flanges of the wheels run, thus obviating the necessity of attaching wrought-iron rails. B B are the double wedge-shaped pieces connected together in the centre by adjustable links.

Fig. 3.

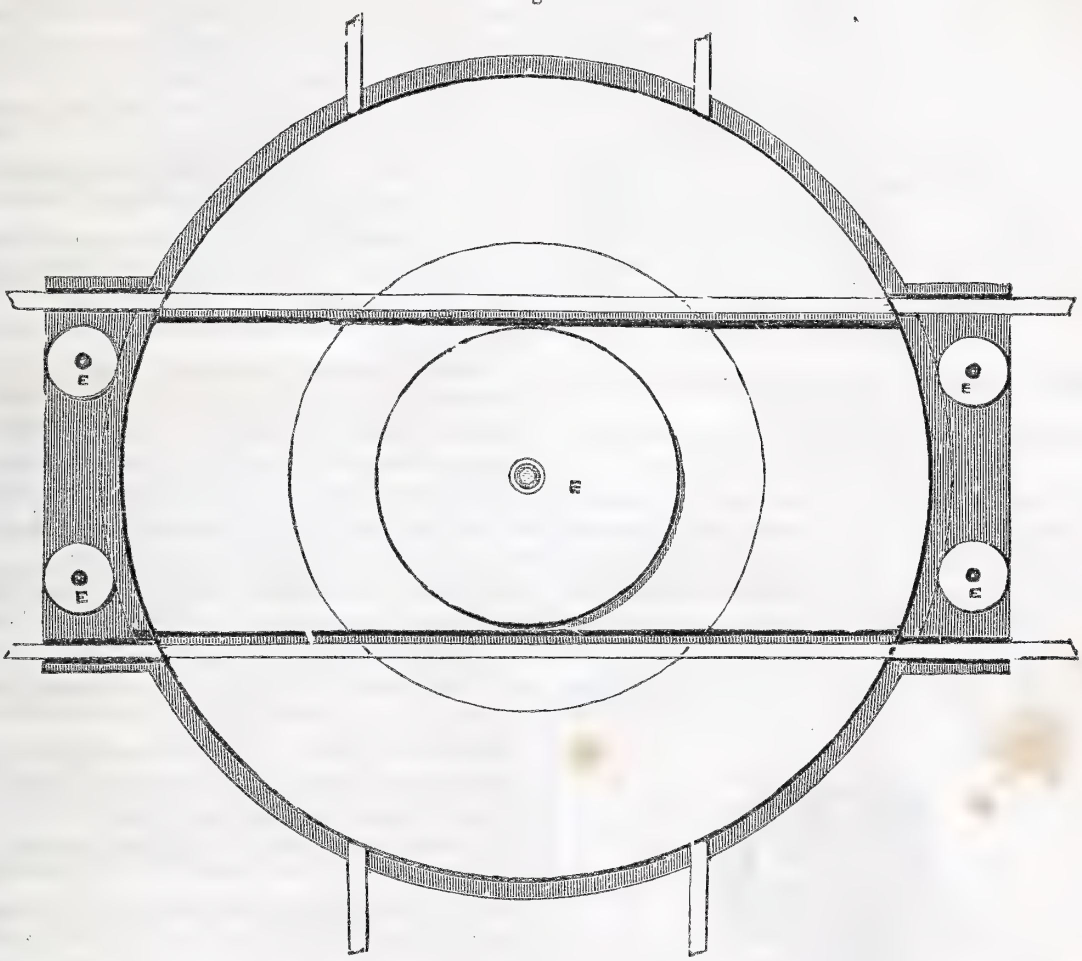


Fig. 4.

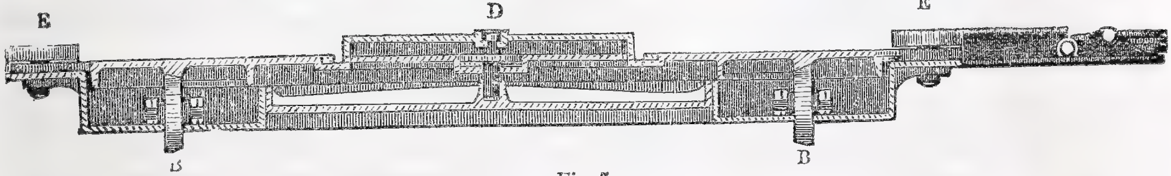
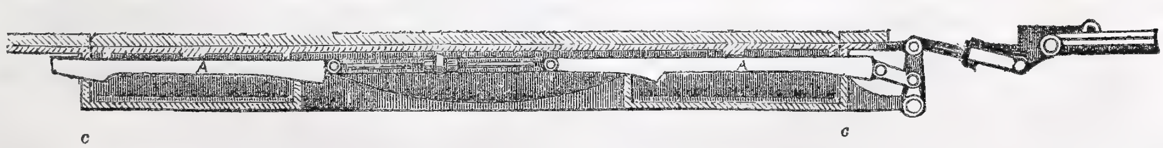


Fig. 5.



It will be seen that the flat upper surface of the wedges support the platform by means of a series of projecting flanges cast on the under surface of the latter, the angular wedges resting upon similar flanges cast on the foundation plate. In their position, as has been shown, the table is supposed to be arranged for the passage of carriages, the whole weight being transferred from the supporting wheels to the wedges. To replace it so as to permit of its revolving, the lever handle C must be raised, which will cause the wedges to traverse, and

allow the table to settle down in its original position upon its wheels.

Fig. 3 exhibits a ground plan of a table furnished with similar steadying gear, but provided with additional apparatus for the purpose of guiding the carriages over the platform, although the latter should be left out of line with the permanent rails. Fig. 4 is a vertical section through the centre of the platform, showing the conical supporting pulleys B B and the central pivot D, and fig. 5 is a section showing the arrangements for moving the supporting wedges A A. In this table the platform is one entire disc, supported by a series of conical pulleys B B, working in bearings attached to the foundation plate C. It is steadied and retained in its central position by the pin D, working in a recess of a central casting placed within the annular foundation plate. E E E E are four guide rings attached to a flange of the foundation plate outside the platform; they, as well as the central ring F, are for guiding the carriage wheels, should the tracks on the table be accidentally left out of line with the rails.

The diminution of the depth required for these tables is not the least of their advantages, as the great depth of the ordinary pillar tables precludes their introduction in many situations, as on viaducts and the floors of warehouses. The addition of the guides D D is also one of considerable moment, as although, in case a train passes over the table, while the ways are not lineable, the carriages will sustain a considerable shock by the rise caused by the flanges coming upon its surface, yet they will be guided straight to the opposite rails, by reason of the rings catching the inside of the flanges of the wheels.

PREPARATION AND COLORATION OF CAOUTCHOUC,

AND APPLICATION OF THIS SUBSTANCE TO EVERY KIND OF FABRIC.

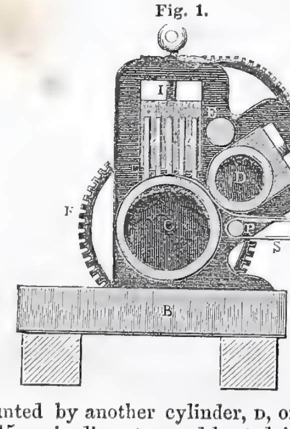
By M. Storrow.

This invention is divided into two parts: the first consisting of a machine, by means of which the caoutchouc is subjected to a treatment which brings it to a suitable state for being applied to the cloth, or any other substance, to be rendered waterproof. The second part embraces the machine by which the caoutchouc so prepared is actually applied to the fabrics.

The first of these machines is represented in fig. 1, in vertical section.

It is a hollow cylinder, 1·8 metres in length, and 0·68 metres in diameter, heated by steam or otherwise to about 95° Cent.,

Fig. 1.



and surmounted by another cylinder, D, of the same length, but only 0·45 m. in diameter, and heated in the same manner.

The two cylinders touch one another lengthwise, at about 0·25 m. distance from the upper generatrix of the large cylinder.

The cylinder, C, turns much quicker than the other, D, so that betwixt the two a compound action is produced, partly rotatory, partly a sliding movement.

Five bars, *a*, fitted into grooves in the iron squares, H, and the height of which is regulated by means of the screw, I, are placed parallel to each other at intervals of 20 millimetres, and touch with their lower ends the periphery of the cylinder, C. These bars are 1·8 m. in length, 0·30 m. in width, and 38 millimetres in thickness.

The lower extremity of these bars, which, as we have said, is in contact, or nearly in contact, with the surface of the cylinder, C, is convex or circular, so that when one of the edges of the line touches the cylinder, the other is at some distance from it, leaving thus a uniform space to permit the caoutchouc to penetrate under the bars.

This inferior line of the bars forms, therefore, two angles, the one acute, the other obtuse, more or less, according to their situation in respect to the cylinder.

These bars take the place of an equal number of cylinders, but they are better fitted for the equal distribution of the colouring matter with which it is intended to stain the caoutchouc; they are kept in contact, or nearly in contact, with the cylinder, either by the screw, I, already mentioned, or, if preferred, by weights adjusted for that purpose.

When the caoutchouc is to be coloured, the colouring matter, reduced to powder, and well sifted, is placed in the spaces existing between the bars and the cylinder.

An endless web, S, fitted to the machine, and moving on the rollers, P and Q, serves to convey the caoutchouc between the two cylinders, C and D.

A is the cast-iron frame of the machine, and B wooden beams on which it rests; E is a driving shaft, carrying a pinion which gears with the wheel, K, mounted on the axis of the cylinder, C, which it puts in motion.

The proximity of the cylinders, D and C, is regulated by means of a screw, J.

The machine operates in the following manner:—

The caoutchouc, cut into pieces of 12 to 13 centimetres square, and of a thickness varying from 3 to 6 millimetres, is spread on the endless web which conveys it to the cylinders; and these cylinders being heated, their action partly rotatory, partly sliding, softens and draws out the caoutchouc into thin sheets or slender filaments, passes it under the bars, *a*, and at the same time mixes it with the colouring matter which has been put into the spaces existing between the bars.

In this manner the caoutchouc passes under each of the bars, *a*, successively, and undergoes this operation several times before it is properly prepared to be applied to the fabric by the second part of the apparatus.

To colour the elastic gum, it may be reduced into sheets, the colouring substance applied to it, the whole rolled into a mass, and afterwards passed between the cylinders till it is sufficiently coloured.

The colour may likewise be mixed with small pieces of the elastic gum, and these made to pass together between the cylinders, or between the cylinder and the bars; the colour is added till the elastic gum is sufficiently coloured.

The machine for spreading the caoutchouc, so prepared, on the cloth or other materials, is represented in vertical section in fig. 2.

It is composed of four hollow cylinders, 1·8 m. in length, heated, like those of the machine already described, by steam or otherwise, to about 95° Cent.

These cylinders are denoted by 1, 2, 3, and 4; they are mounted over one another in the frame, A, and the cylinders 1 and 4 are put in motion by the toothed wheels, H and I.

Cylinder 1 is 0·45 m. in diameter; cylinders 2 and 3, 0·30 m.; and cylinder 4, 0·45 m.

Cylinder 3 turns much more slowly than the others, so as to produce an action of mingled rotation and sliding between the surfaces of the cylinders 2, 3, and 3, 4.

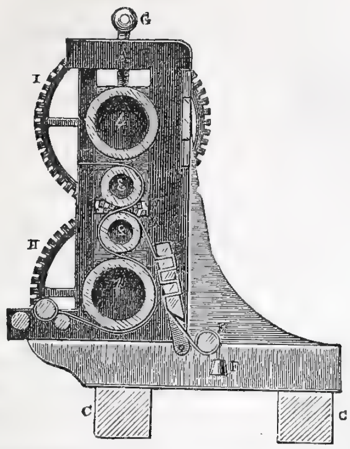
Sometimes only the first three cylinders are used. In this case cylinder 4 is put out of gear, and the fabric or other material to be coated with caoutchouc passes to the spreading machine between the second and third cylinder; from thence it passes partly round cylinders 1, 2; the side on which the caoutchouc is spread, coming in contact with cylinder 1, traverses almost its whole circumference, and is then taken up and wound on a drum, Q, which moves, by friction or adhesion, the roller, P.

The fabric is given out from a drum, E, furnished with a counter-weight, F, which serves to keep it stretched. It then passes between bars or *cheeks*, D, and penetrates at last between the cylinders.

The caoutchouc, still warm, is taken by hand or otherwise,

from the machine in which it is prepared, and is poured into a funnel-shaped vessel, not shown in the figure, but opening at

Fig. 2.



the point, v, between cylinders 2 and 3. This funnel is narrower by 5 centimetres, than the fabric to be coated with the caoutchouc. The cloth passes between the bottom of the funnel and cylinder 2, while the caoutchouc is introduced between that part of the funnel and cylinder 3, where the application of the caoutchouc takes place.

It is attended with advantage to pass the caoutchouc between cylinders 3 and 4, by adjusting the funnel with its lower part at the point, u, before bringing this substance in contact with the fabric. In this manner the caoutchouc is heated and softened, and is thus prepared to adhere more firmly to the stuff on which it is distributed, more uniformly than when it is applied directly on coming out of the funnel.

Sometimes the prepared caoutchouc is poured directly on the cloth or other substance to be coated with it, between the cylinders 2, 3, and then the cylinder 4 is put out of gear, which consequently remains at rest.

The bottom of the funnel, in this case, does not penetrate so far between the cylinders.

The sides of the funnel advance, in all cases, as far forward as possible, without being in the way of the cylinders, to which they should be well adjusted.

Another manner of using this machine is as follows :—

The caoutchouc enters by itself between the cylinders 2 and 3, where it is converted into a sheet which passes round cylinder 2. The cloth enters at the same time between cylinders 1 and 2, and then the sheet of caoutchouc quits the cylinder to adhere to the stuff, and afterwards traverses almost the whole circumference of the first cylinder, after which it is taken and rolled up as before.

The machines which we have just decribed form only one whole, although, in the figures, to convey a more distinct idea of the different parts, they have been divided and represented as two.

PROTECTION FROM LIGHTNING OF HOUSES WITH METALLIC ROOFS.

(From the Proceedings of the American Philosophical Society.)

Professor Henry made a communication relative to a simple method of protecting from lightning buildings covered with metallic roofs.

On the principle of electrical induction, houses thus covered are evidently more liable to be struck than those furnished either with shingle or tile. Fortunately, however, they admit of very simple means of perfect protection. It is evident, from well-established principles of electrical action, that if the outside of a house were encased entirely in a coating of metal, the most violent discharge which might fall upon it from the clouds would pass silently to the earth, without damaging the house or endangering the inmates. It also is evident, that if the house be merely covered with a roof of metal, without projecting chimneys, and this were put in metallic connection with the ground, the building would be perfectly protected. To make a protection, therefore, of this kind, the professor advises that the metallic roof be placed in connection with the ground, by means of the tin or copper gutters which serve to lead the water from the roof to the earth. For this purpose, it is sufficient to solder to the lower end of the gutter a riband of sheet copper, two or three inches wide, surrounding it with charcoal, and continuing it out from the house until it terminates in moist ground. The upper ends of these gutters are generally soldered to the roof; but if they are not in metallic contact, the two should be joined by a slip of sheet copper. The only part of the house unprotected by this arrangement will be the chimneys; and in order to secure these, it will only be necessary to erect a short rod against the chimney, soldered at its lower end to the metal of the roof, and extending sixteen or twenty inches above the top of the flue.

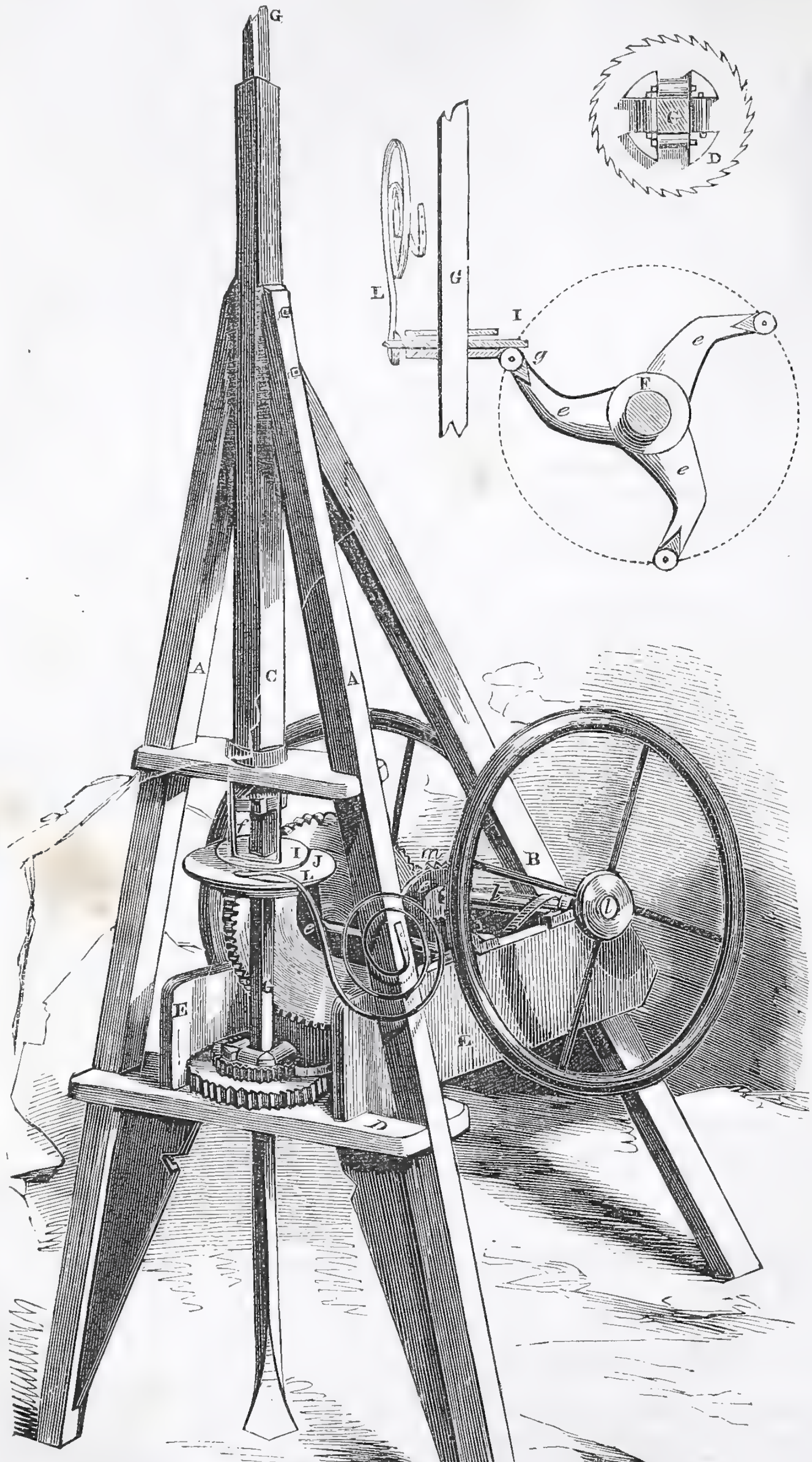
Considerable discussion in late years has taken place in reference to the transmission of electricity along a conductor, whether it passes through the whole capacity of the rod, or is principally confined to the surface. From a series of experiments presented to the American Philosophical Society by Professor Henry on this subject, it appears that the electrical discharge passes, or tends to pass, principally at the surface; and as an ordinary-sized house is commonly furnished with from two to four perpendicular gutters (generally two in front and two in the rear), the surface of these will be sufficient to conduct silently the most violent discharge which may fall from the clouds.

Professor Henry also stated, that he had lately examined a house struck by lightning, which exhibited some effects of an interesting kind. The lightning struck the top of the chimney, passed down the interior of the flue to a point opposite a mass of iron placed on the floor of the garret, where it pierced the chimney; thence it passed explosively, breaking the plaster, into a bed-room below, where it came in contact with a copper bell-wire, and passed along this horizontally and quietly for about six feet; thence it leaped explosively through the air a distance of about ten feet, through a dormer window, breaking the sash, and scattering the fragments across the street. It was evidently attracted to this point by the upper end of a perpendicular gutter, which was near the window. It passed silently down the gutter, exhibiting scarcely any mark of its passage until it arrived at the termination, about a foot from the ground. Here, again, an explosion appears to have taken place, since the windows of the cellar were broken. A bed, in which a man was sleeping at the time, was situated against the wall, immediately under the bell-wire; and although his body was parallel to the wire, and not distant from it more than four feet, he was not only uninjured, but not sensibly affected. The size of the hole in the chimney, and the fact that the lightning passed along the upper wire without melting it, show that the discharge was a small one; and yet the mechanical effects, in breaking the plaster and projecting the window-frame across the street, were astonishingly great.

These effects, the professor attributes to a sudden repulsive energy or expansive force developed in the air along the path of the discharge. Indeed, he conceives that most of the mechanical effects which are often witnessed in cases of buildings struck by lightning, may be referred to the same cause. In the case of a house struck within a few miles of Princeton, the discharge entered the chimney, burst open the flue, and passed along the *cockloft* to the other end of the house; and such was the explosive force in this confined space, that nearly the whole roof was blown off.

Dr. Patterson stated, that Mr. Jefferson was of the opinion that metal roofs protected buildings, not from being struck, but from the danger of the stroke. The contrary opinion is generally held; but Professor Henry's experiments show that Mr. Jefferson was correct. Dr. P. saw the lightning strike a row of dormitories with metal roofs, at the University of Virginia. The flash was very severe, but produced no evil effect; the lightning had spread itself over the surface, and left its mark at each interruption of the conductor, but did no damage.

IMPROVED ROCK DRILL.



THE accompanying engravings represent an improvement in rock drills, for which a pa e t was granted to Edward G. Dunham, of Portland, Conn., U. S., on the 10th October, 1854.

Figure 1 is a perspective view; figure 2 is an elevated section of the lifting arms, the drill bar, and spring; and figure 3 is a top view of the ratchet wheel for turning round the drill bar, G, and it also shows the roller collar box of the drill bar. Similar letters refer to like parts.

A is the frame, with an inclined back post, B, and side bearers, E E; C is the drill box through which the drill bar, G, moves; D is a lower girt of the frame, the upper one sustains the drill box; *l* is the driving shaft, with a fly wheel and crank on each end, for one man on each end to operate the machine; *m* is a cog pinion on the main shaft, *l*, gearing into the cog wheel, *n*, on the shaft, K (figure 2), inside of the frame, on which shaft are the lifter arms, *e e e*, which are cast on a hub, F, secured on said shaft; *g* is a friction roller on the end of each lifter arm. Two long spring ratchets take into the teeth of the ratchet wheels surrounding the drill bar, G, and resting on the lower girt, D. The end of one of these ratchets is shown taking into the teeth of one wheel in figure 1, but nearly all the rest of it is hid. They are secured around the main shaft, and at every revolution take into a new tooth, and thus make the drill strike into a new place every stroke, and gradually revolve it. L is a stout steel spring, with one end secured to the frame, and the other resting upon the lifter plate, I, on the drill stock. The recoil of this spring, when the drill falls, imparts additional force, and gives a greater blow than that acquired from the weight of the drill alone; D′, in figure 3, is one of the ratchet wheels for moving the drill stock round; *a a* and *b b* are collar boxes, with friction rollers in them, to allow the drill stock to play smoothly through them; figure 3 shows one of these collars; I is the first friction plate, placed loosely on the drill stock, with its central opening a little larger in the diameter than the drill bar. It is held in place by the spring, L, but is also allowed to incline itself, when lifted by the arms, *e*, of the lifter and bite on the drill, and descend with it; J is a small friction plate for catching and holding the bar when not in use,

by being inclined and held by a stirrup catch, *f*, figure 1. When not in use for holding the bar, G, this small plate moves up and down loosely with the lifter plate, I. The lifter having three arms, the drill is raised and strikes three times during one revolution of the shaft, K. A worm wheel can be employed to turn the drill, in place of the pallet and ratchet wheels. The drill box, C, may be made to open at one side, so as to take out the drill bar more easily, when required. As the lifter revolves, the arms, *e e e*, alternately come under and raise the plate, I, figure 1, and thereby raise the drill; and then, when each has attained to the highest point of its revolution, it slips out, and the drill falls. When it is desired to lift out the drill, the top of the spring, L, is released from the top of the lifter plate, I. There is a soft buffer of leather, or other such substance, placed under the lifting plate, I, so as to make it strike softly upon the collar box, *b b*, when the drill falls.

The claims of this patent are in substance as follows:—1st. Arranging a horizontal plate on the drill rod, and by bringing the lifter in contact with it in the manner described, it will be caused to incline slightly during the raising of the drill bar, and consequently will bite upon said bar, and hold it firmly until it is raised to the position desired, and as the lifter escapes, again assumes nearly a horizontal position, then quits its hold and falls with the drill. 2nd. Rendering the lifter plate, I, for raising and dropping the drill bar, adaptable for removing the said bar entirely out of holes when drilled, by employing the small friction plate, J, on its top, which can be set inclined to hold the drill bar, as it is gradually raised. 3rd. The small plate, J, is claimed, whether used in connection with the plate, I, or not, when it is sufficiently inclined to hold the drill bar by the catch, *f*, by any means employed for so doing this, to retain the bar while the machine is being lifted. 4th. Accelerating the descent of the drill bar, and increasing the force of the blow, and increasing the friction on plate, I, upon the drill bar by the spring, L.

Mr. Dunham states that two men with this machine can do the work of eight. It can drill a perfect round hole from two to ten inches in diameter, and twelve feet deep, without any connecting-rod. By means of a tin cannister, employed to contain the charge in these holes, the rock can be split in any direction required.

HISTORY OF PHYSICAL SCIENCE.

CHAPTER IV.

PHILOSOPHY OF ARABIA AND MEDIÆVAL EUROPE.

With the gradual decay of the Roman empire begins a period in the intellectual history of mankind too often misunderstood—the so-called "decline of learning." Many consider this "decline" as an essential and unmistakable retrograde movement, and therefore as an exception to the law of evolution of our race. But this is a misconception. About the facts there can be no dispute, but how are they to be interpreted? It is now well established that a class of men, placed in circumstances of *exceptional* comfort, such as an aristocracy, or the free population of a slave-holding state, is liable to decay—a decay not merely in point of numbers, but in that vigour and energy needful for action and speculation. We know that the free populations of Greece and Rome actually declined in this manner, whilst the vacancy was supplied by an increased number of slaves. These slaves, chiefly natives of barbarous countries, excluded from all opportunities of mental culture, could, of course, contribute nothing towards the intellectual life of the country.* Science therefore declined for mere lack of cultivators—a want springing from the peculiar institutions of the Roman empire, not from any cause of a universal nature. But as all the civilization of the age was included within the boundaries of the Roman empire, the decay seemed universal.† To this were added a variety of other causes. The whole intellectual vigour of Europe for many ages was absorbed in effecting the transition from polytheism to monotheism—in other words, in the propagation and establishment of Christianity. Now, although this change was ultimately favourable to the onward progress of our race, it yet temporarily withdrew public attention from physical science.‡ Again, as the crisis of the ancient world drew on, outward convulsions proved a formidable hinderance to learned pursuits. Not, indeed, that war is in itself incompatible with the prosperity of science and literature; but, in the age in question, all stability, all public order had disappeared; definite nationalities no longer existed; Europe was in a state of violent and turbid fermentation. Language itself, from the perpetual migrations and intermixture of alien tribes, was constantly fluctuating. Hence not merely the propagation, but the clear conception of ideas became difficult. Lastly, the irruption of the northern barbarians filled southern Europe with a population still in the primitive state, still immersed in the personifying or supernatural epoch. What wonder that no progress in philosophy was possible, until this mixed multitude had been educated up to the point already reached? By the help of these considerations, our readers will be able to understand the "decline" of learning in its true light, and to see that any repetition of such a phenomenon in the future career of the world is all but impossible.

The intellectual history of such a period must necessarily appear somewhat unsystematic. We find many abortive attempts at reorganization proceeding from superior minds, before the world was ripe for their reception. We may, however, recognise three distinct epochs, in which the centre of intellectual activity successively appears at Byzantium, among the Arabs, and in Western Europe. The earliest of these periods is the least fruitful in considerations of interest. The Greeks of the Eastern empire possessed, indeed, the philosophic works of their forefathers, but were not actuated by the same spirit. As thinkers, they were paltry, narrow, impotent, devoid of any grasp of mind, and incapable of forming any original ideas. Schools of philosophy, indeed, existed, in which the learned expounded the works of Aristotle and Plato, and very industriously sought for the living among the dead. The "commentatorial spirit," which, as Whewell justly remarks, is a sure mark of declining mental vigour, appeared here in full play. To abridge the works of ancient authors, to collate their opinions, or attempt a reconciliation between rival systems, was easier than original research. Controversies on matters the most trifling were conducted with a vehemence truly scandalous. The Emperor Justinian, a sham philosopher and genuine pedant, closed the schools of Athens, and withdrew the grants formerly appropriated to educational purposes in many parts of the empire. Leo, the Isaurian, burnt an extensive and valuable library, together with the members of the imperial academy, who had unfortunately earned his displeasure. The talents and industry of Photius, in the ninth century, effected a temporary revival. Michael Psellus, in the reign of Michael VII., gained the proud title of "Prince of Philosophers." He is said to have written a treatise on alchemy. His knowledge of the sciences, though extensive, was merely verbal, and therefore fruitless. The temporary conquest of Constantinople by the western crusaders led to very unfortunate results. Not only the most magnificent works of art, but the literary treasures collected in the city, were destroyed by the ignorant and brutal invaders. After the restoration of the Greek emperors, the intercourse between the east and the west rapidly increased, a circumstance favourable to intellectual revival. The remaining period, up to the capture of Constantinople by the Turks—on which occasion a hundred and twenty thousand ancient manuscripts are said to have been destroyed—is utterly void of interest. The remnants of Greek learning now found an asylum in Italy, where they were more fully appreciated.

PHILOSOPHY OF THE ARABIANS.

The early career of the Mahommedan dominion offered very unfavourable prospects to science. Even though doubts may

* Ignorance, like water, will find its own level. Besides, of all situations, the most unfavourable for spiritual development is that of a savage plunged at once into the midst of a luxurious society.

† Hence we see the insecurity of civilization if committed to the charge of one people alone, and the danger of universal empires.

‡ Physical science, strictly speaking, is the form which all knowledge must assume when sufficiently demonstrated and co-ordinated.

rest upon the destruction of the Alexandrian library, it is clear that the Saracen conquerors, in the first upburst of their zeal, looked with indifference, if not with actual enmity, upon intellectual pursuits. With the consolidation of the empire, and the accession of the Abassidi dynasty, a new era began. Bigotry gave place to an enlightened toleration, and Bagdad for a time became the great capital of the learned world. Almanzor, Haroun-al-Raschid, Almamon, and other caliphs, invited learned Christians and Jews to their court, and treated them with every distinction. Colleges for the diffusion of science were founded and amply endowed, and manuscripts were collected and preserved in the public libraries. The Fatimite sultans of Africa, and the Ommiades in Spain, pursued a similar policy. The former amassed, at Cairo, a library of one hundred thousand volumes. The academy of Cordova was attended by students from all parts of western Europe, and its library contained 280,000 volumes. Seventy other public libraries existed in Andalusia alone. What was the result of all this patronage, of these ample means and appliances? It might have been hoped that the Arabs would have displayed in philosophic research the same energy which had borne them on as conquerors from the Indus to the Atlantic—that a new people would have originated new methods of inquiry, new ideas in science. Such was not the case. Authors innumerable indeed arose, but arose merely as the blind followers of their Greek masters. They did not, as some have imagined, by their "experimental intellect," supply what the "abstract intellect" of Greece had omitted. Their systematic philosophers fixed their attention chiefly upon the "Physics" of Aristotle, who in practice fell far short of his own method. Like the later Greeks, they compiled, abridged, and commented, instead of discovering. Their chemical operations belong rather to the industrial arts than to science, although they undoubtedly furnished matter for future investigators. Their chief contribution to mathematics was the modern system of numbers, a Hindoo invention, which the Arabian scholars introduced into Europe. Mohammed Ben Musa, of Khorarezm, the earliest Arab writer on algebra, treats of the solution of simple and quadratic equators. His matter is borrowed from Indian sources. The astronomical researches of the Arabs have been described elsewhere. To the physical knowledge of mankind they added little or nothing. Their acquaintance with the laws of force and motion was exceedingly limited. The opinion has latterly sprung up, that the Arabs first discovered the polarity of the magnet, and communicated this fact to the Chinese. Their earliest chemical writer was Geber (Dschafar), who flourished in the eighth century. He considers the metals as compounds of mercury and sulphur, and therefore as capable of mutual conversion—the germ of alchemy. He treats of the structure of furnaces, of distillation, of the water-bath, of cupellation and filtration. He is acquainted with the solution of metals in the mineral acids. He distinguishes potash from soda, and describes their preparation. He is the earliest writer who gives a correct account of saltpetre and sal-ammoniac. He made use of alum, and obtained from it a weak kind of sulphuric acid. He employed borax in the reduction of metallic oxides. Nitric acid he prepares by distilling to dryness a mixture of sulphate of iron, saltpetre, and alum. In the acid thus obtained he dissolves silver, and by the addition of sal-ammoniac he obtains an aqua regia, capable of dissolving gold and sulphur. He describes, in an intelligible manner, the preparation of corrosive sublimate, cinnabar, and red oxide of mercury. He was aware that the alkalies dissolve sulphur, and was probably acquainted with metallic arsenic. All this knowledge was, however, utterly empirical, not philosophic. He accounts for phenomena by means of occult principles, and never attains conceptions truly scientific.

Ebn-Sina (Avicenna), of Bokhara, was born about the end of the tenth century. As a chemist, he made no addition to the facts handed down by his predecessors. His great medical work, the *Canon*, which, for several centuries, was held almost sacred in the schools, is equally wanting in originality, though it may claim the merit of a luminous arrangement. Ebn-Roshdt (Averrœs) flourished about the end of the eleventh century at Cordova. Though possessing great erudition, he was a servile follower of Aristotle. Amongst his medical writings, the "Kulizat," or "Totality," is the most important. The philosophy of the Arabians was, therefore, a complete failure. Unable to make any vital addition to the works of their predecessors, they had, by adopting the commentatorial system, proclaimed the fact of their own impotence. The cause of this failure lies partly in the eminently unscientific character of the Semitic race, partly in the depressing influence of their religion, and partly in the fact, that with them philosophy was a mere exotic, suddenly introduced by the caliphs into an unprepared soil. The merit of the Arabian writers lies in their having preserved in their schools the science of Greece, and distributed it over Europe. In the practical arts they take a far higher standing.

From this point of view their chemistry was eminently progressive. Their acquaintance with gunpowder appears a matter of certainty. Their pharmaceutists introduced a variety of new medicines into practice, such as opium, manna, assafœtida, and mercurials. The manufacture of paper either originated with the Arabs, or was borrowed by them from India as early as the eighth century.

PHILOSOPHY OF MEDIÆVAL EUROPE.

In western Europe the human mind remained longer dormant, although, when aroused, it very soon manifested a higher activity than that of Byzantium or Bagdad. With the decay of the Roman empire the schools had fallen into decay, or had lingered on under ecclesiastical auspices.* In France, Germany, and Britain, none save monks and priests were able to read and write. Italy offered a somewhat more consolatory aspect, but even there learning was confined within very narrow limits. Philosophic inquiry was neglected, or even viewed with mistrust. So far had the scientific discoveries of former times been lost, that Lactantius, in the fourth century, on theological grounds, asserts the earth to be a vast extended plain, and denies the possibility of antipodes. In the eighth century, Virgilius, bishop of Salzburg, was censured by his superiors for asserting the existence of antipodes, and Tostatus, only a few years before the expedition of Columbus, pronounces the rotundity of the earth an unsafe doctrine. The first systematic attempts for the restoration of learning, were made by Alfred and Charlemagne. Schools were founded, where the clergy, at least, might be educated, and two courses of study were marked out, the *Trivium*, consisting of grammar, dialectics, and rhetoric; and the *Quadrivium*, comprising music, arithmetic, geometry, and astronomy. These were called the "seven liberal *arts*" (the respective distinctions between science, art, and erudition being then little understood), and comprised the whole circuit of ancient learning. At an early date, however, dialectics, or logic, began to acquire a decided predominance over its associates. Every departure from established usage was, however, denounced as dangerous, and subjected the offender to ecclesiastical censure. It was in these schools that the scholastic philosophy originated, which for several centuries bore sway over all Europe. Scholasticism may be defined as a compromise between theology and metaphysics, an attempt to amalgamate and reconcile the systems of Aristotle and Plato with the teachings of Christianity. For us this system is of no further importance than as an important agent in the general education of the times. Frivolous as were the immediate questions discussed by the scholastic doctors,† as a mental discipline they were invaluable. The function, or, as some say, the "mission" of scholasticism was to cultivate subtilty of thought, to undermine the grossly supernatural conceptions which, in an age of ignorance, had again become prevalent, and to replace mankind on the vantage ground of the Greek metaphysical philosophy. This effect was fully realized; in logical subtilty and acuteness, the scholastics even surpassed their Greek masters, and by their failure gave additional evidence of the vanity of ontological research.‡ The

* From this merely accidental circumstance springs the claim of the clergy to a special control over public instruction—a power far too vast to be placed in the hands of any one order of society.

† As—*e. g.*—how many angels could stand upon the point of a fine needle!

‡ Ontology, an inquiry into the essence of things, or into *noumena*, in opposition to positive science, which investigates *phenomena*, their properties, as manifest to our senses.

evils inseparable from the system were a neglect of the dictates of common sense and of practical utility—two faults which, in time, brought about their own cure. The most important event of the period was the great discussion between Realism and Nominalism, with the ultimate triumph of the latter. The realists assumed that general terms—the "ideas" of Plato—had an actual, objective existence; whilst the nominalists declared them mere abstractions of the human mind. The contest was not carried on by argument alone. The realist doctrine received the sanction of the Church, and was enforced by pains and penalties. Pope John XXIII. subjected the nominalists to a severe persecution. In 1339, they were expelled from the University of Paris, and, in 1473, Louis XI. ordered their writings to be seized. The leaders of the realists were Champeaux, Albert the Great, Thomas Aquinas, and Duns Scotus. Among the champions of nominalism we find Roscellin, Abelard, and Occam. The contest did not entirely cease until the rise of physical science drew off attention to more important topics. The part played by the monks in respect to science, whilst some have viewed them as the faithful guardians of learning, others have considered them as its oppressors. In both these views there is an element of truth. The monasteries, when first established, undeniably afforded an asylum for scientific pursuits not otherwise to be found. There manuscripts were preserved and collected; there a knowledge of the Latin language was maintained; and there, above all, peace and security were enjoyed under the sanction of religion. Most of the eminent men in the middle ages were monks. That the cloister was not a perfect school of science, that it imposed a variety of restrictions upon the freedom of thought and research, is true; but, in the absence of better institutions, was it not invaluable? The meanest hut is a welcome shelter in night and storm. By degrees, however, a change appeared. As civilization and learning increased, the value of the monasteries became less and less; from leading the van of human progress they fell into the rear, and, like every other institution whose mission is fulfilled, they became internally corrupt. It is from this, its period of decline, that the vulgar notions of monastic life are too exclusively taken. Let us never forget that these much-decried establishments maintained the spiritual life of the world when all around was shrouded in darkness; and that the monks cherished truth, according to their insight, for its own sake, regardless of market value. Amidst all rudeness, the men of those days paid to their saints an amount of reverence which the spiritual guides of the modern world, the philosophers, and poets, might vainly seek. Among the intellectual characteristics of the period, Whewell considers as especially predominant the commentatorial spirit, mysticism, dogmatism, and servility, or the blind worship of authority. The two former of these tendencies we have already explained. The two latter are more closely connected than we may at the first glance perceive, since tyranny and slavery are phases essentially correlative. The man who surrenders unhesitatingly his own right of private judgment, will be little apt to respect the same right in others. The persecuting dogmatism of the Mediæval epoch will claim our attention elsewhere. The universally acknowledged authority was Aristotle, not in the original state, but seen through the medium of bad Latin translations from the Arabic, and further obscured by the commentaries of inferior minds. The illustrious thinker of Stagira is often blamed for the abuse made of his writings and influence. This is decidedly unjust. Had the Scholastics possessed the *Novum Organon* of Bacon, and the *Principia* of Newton, they would merely have commented upon them, and be-quibbled them, and sought in them texts for verbal disputation. The reign of Aristotle was not without its fluctuations. His writings were alternately recognised and denounced by the ecclesiastical authorities, until they were finally received as the standard of truth.

Discoveries in science we cannot, strictly speaking, here anticipate. A few illustrious characters appear, whose conceptions, far in advance of their day, bear the impress of a higher philosophic character; but the principal part of the knowledge accumulated was strictly empirical.

Gerbert, afterwards Pope Sylvester II., studied mathematics and astronomy with great zeal, and introduced the Arabian numerals about A.D. 1000. He constructed armillary spheres, observed the stars through tubes, invented a clock of tolerable accuracy, and a hydraulic organ. He may be characterised as the first and last philosopher who filled the papal chair. Like many other scientific characters of early times, he was accused of sorcery. Richard of St. Victor wrote on scientific method, attempted a classification of the sciences, and clearly distinguishes between theory and practice. His definitions of mathematics and physics are very judicious. He even declares that "science ascends from effects to causes, and descends again from causes to effects," a remark which, as Whewell observes, "Bacon himself might have adopted." Albert of Bollstädt, surnamed the Great, a servile follower of Aristotle, made the first attempt at cerebral psychology, by locating the faculties of the mind in different parts of the brain. It is needless to add, that he proceeded entirely upon *a priori* principles. He was a painstaking chemist, in the only sense which the word could bear in those days—hodman rather than architect. He was acquainted with the works of Geber, and operated (I do not say experimented) on red lead, arsenic, and the alkaline sulphides, then called liver of sulphur. Although he considered mercury and sulphur as the constituents of metals, he yet, with Thales, considered water as of a more truly elemental nature. Raymond Lully, a native of Majorca, in the thirteenth century, felt the inadequacy of the prevailing method, and attempted a reformation. His *Ars Magna* professes to be a certain guide to truth. In it he tabulates and classifies all possible conceptions. His first class contains nine *absolute ideas*—goodness, greatness, duration, power, wisdom, will, virtue, truth, majesty. The second is composed of nine *relative ideas*—difference, identity, contrariety, beginning, middle, end, majority, equality, minority. The third contains nine *questions*—whether, what, whence, why, how great, how circumstanced, when, where, and how. These ideas are grouped in moveable concentric circles, which, when set in motion, are to give true propositions on any subject without the labour of thought. That such a method could not lead to any truth of value, will require little demonstration. As the first systematic protest against the scholastic Aristotelianism, however, the *Ars Magna* is of high significance. The human mind was beginning to feel that something more solid and profound than mere verbal disputation was requisite. And with all its faults, the new system was pervaded by a deep conviction of the unity of all cosmic forces. Lully maintains that the reason, setting out from doubt, should seek not faith but knowledge, and, with a prophetic insight, seeks to free science from ecclesiastical control. We may concede him, therefore, a worthy place among the reformers. His chemical acquirements were great. He first introduced a system of symbols; he studied the phenomena of deliquescence, improved the manufacture of nitric acid, operated upon ammonia, and had high opinions of the virtues of alcohol. He first drew attention to the volatile products of decomposition—an important step, as it undermined the vulgar error of the destructibility of matter. Arnold of Villa Nova flourished about the same time. His studies embraced chemistry and medicine, in which art he attained a distinguished proficiency. He was acquainted with metallic bismuth, and appears to have discovered the oil of turpentine. He was accused of heresy, and subjected to much annoyance.

Isaac the Dutchman (Hollandus) and his son wrote subsequently to Arnold. They were clear, painstaking compilers, but unable to originate anything new.

So much for the scholastic epoch, or, as Whewell calls it, the "stationary period." The epithet is unjust. The *elite*, the vanguard of mankind, may at times move slowly, but its career is never quite arrested. The fifteenth century witnessed the general downfall of scholasticism. Its work was accomplished; it had, in the cultivated minds of Europe, effected the full triumph of the metaphysical over the supernatural mode of conception. A variety of causes, inward and outward, now prepared the way for a more efficient system, for the advent of Positivism. The industrial arts had not been dormant. Architecture, under the inspiration of Catholicism, made important advances. But architecture involves, at least, a tacit knowledge of the great principles of mechanics. It affords

innumerable instances of the laws of force and pressure, and thus contributes to their discovery. The construction of canals, an art practised by the Lombards and Dutch at an early period, gave further scope for engineering skill, and led to a knowledge of the equilibrium and pressure of fluids. Many of the works executed at this time, as the canal from Milan to the Tesino, completed in 1271, are still admired for the excellence of their construction. It is perfectly true, that engineering of many kinds may be practised, as in China and ancient Egypt, by rule of thumb, without the acquisition of any scientific ideas. But the mind of mediæval Europe was now fast approaching a state fit to take advantage of the opportunities of observation thus placed at its command, and to elicit and proclaim those laws of nature which had been hitherto blindly followed.

To suppose, however, with certain of the retrogressionist party, that the architects and master masons of this period actually possessed an explicit knowledge of mechanical science, which they kept carefully concealed, is a perfectly baseless dream. The construction of ships, and the art of navigation, made likewise considerable progress. The polarity of the magnetic needle became known at this time, and was at once applied to nautical purposes. The vulgar story, that the compass was invented at Amalfi, near Naples, from 1300 to 1320, has not the slightest claim to our belief, though Flavio Gioja, a native of the former town, seems to have effected some improvement in the construction of this instrument. Clocks and watches, in a rude form, appear to have been first constructed in the south of Germany, about the end of the fourteenth century. The manufacture of glass made considerable progress, especially at Venice, although even at the end of this period it was still a very rare article in England. The invention of gunpowder is commonly ascribed either to Roger Bacon or to Berthold Schwartz, about 1336; but it was more probably introduced by the Arabs. The invention of printing—an art too fully appreciated to require any panegyric in this place—supplied a guarantee against the loss of any knowledge once acquired. The progress of maritime discovery—the expeditions of De Gama and Columbus, had also their influence, powerful though indirect, on the evolution of the human mind. Not, indeed, that any new principle in abstract science was thus discovered. But an undertaking, successfully carried out in full defiance of old prescription of the authority of the past, revived the faith and courage of our race, and taught it to seek in the future nobler deeds than commenting upon the sayings of antiquity. The "Pillars of Hercules" had been triumphantly past; the world, awaking from its servile worship of authority, shouted an exulting "plus ultra" to all who would stay its career.*

But the grand distinctive feature of this period, as compared with antiquity, is the social importance recognised in industrialism. We have repeatedly intimated, that in antiquity the arts and manufactures were exercised chiefly by slaves, and had hence been treated by the learned with contempt, as quite foreign to their jurisdiction. This stigma was not removed. The arts were exercised by free men—nay, it was among the trading and manufacturing population of the cities that the struggle for constitutional freedom, the attacks upon feudalism, took their origin. Science and art were, therefore, enabled to assume a new relation—to support and enlighten each other, instead of standing aloof in apathy, and even to appear as correlative phases of one and the same fact, man's dominion over the world.

* *Plus ultra*, further yet, the motto adopted by Francis Bacon.

COMPENDIUM OF LOGIC.

CHAPTER V.

PART II. CONTINUED.—OPPOSITION, CONVERSION, AND COMPOSITION OF PROPOSITIONS. PART III.—PRINCIPLES AND RULES OF THE SYLLOGISM.

In last chapter we commenced our synthetical summary by treating of the first or most elementary part of logic, namely, Ideas and Terms—*ideas*, as the objects or results of Perception; and *terms*, as the signs or marks by which we express our Ideas. We then proceeded to the second part of logic, which treats of Judgment and Propositions, explaining, in the first place, the nature and parts of the proposition, and secondly, the different *kinds* of propositions, as divided according to their substance, quantity, and quality. A fourth division, according to their composition, was mentioned, which will be explained in the present chapter; but we must discuss, in the first place, Opposition and Conversion—subjects which relate to the Quantity and Quality of propositions.

OPPOSITION OF PROPOSITIONS.

As every proposition is composed of two terms, namely, the Subject and Predicate, joined or disjoined by the Copula, *is* or *is-not*, *are* or *are-not*, &c., it is evident that different propositions may be formed with the same subject and predicate. Two propositions may be formed in this way by simply varying the *quantity*, or making the one universal, the other particular; as, "All planets are inhabited," "Some planets are inhabited;" and each of these has its negative form, or a corresponding proposition differing only in *quality*, as, "No planets are inhabited," "Some planets are not inhabited." It is evident, therefore, that with any given subject and predicate four distinct propositions may be formed, differing in *quantity* or *quality*, or *both*; and such propositions are said to be *opposed* to each other.

These four propositions, composed of the same *matter*, but differing in form and signification, are distinguished for convenience by the four letters, A, E, I, O, thus:—

A (Universal Affirmative)—All planets are inhabited.
E (Universal Negative)—No planets are inhabited.
I (Particular Affirmative)—Some planets are inhabited.
O (Particular Negative)—Some planets are not inhabited.

This doctrine of the Opposition of Propositions was made by the school logicians the subject of much ingenious trifling and of many ponderous treatises. So important was it deemed, that the following Latin rhymes were composed to assist the memory:—

Asserit A, negat E, verbum generaliter ambœ;
Asserit I, negat O, sed particulariter ambo.*

But, as we regard the subject in a somewhat different light, we shall be content with explaining it very briefly, premising, however, that the logical student will certainly find it convenient to commit to memory the quantities and qualities expressed by these vowels.

Propositions with the same subject and predicate, but differing as above stated, are divided into Contraries, Subcontraries, Subalterns, and Contradictories.

1. *Two universals* (A and E) differing in quality, are *contraries*; as,

A—All planets are inhabited.
E—No planets are inhabited.

These can never be both true together, but they may be both false.

2. *Two particulars* (I and O) differing in quality, are *subcontraries;* as,

I—Some planets are inhabited.
O—Some planets are not inhabited.

These may be both true together, but they can never be both false.

3. Two propositions differing in quantity, but not in quality (A and I, or E and O), are termed *subalterns;* as,

A—All planets are inhabited.
I—Some planets are inhabited.

Or,

E—No planets are inhabited.
O—Some planets are not inhabited.

It is evident that these subaltern propositions, whether affirmative or negative, are not properly opposed to each other, though distinguished, in logical language, as one kind of opposition. The rules or canons for the truth or falsity of such propositions are as follow:—1. *If any universal proposition be true, the particular will be true also, but not on the contrary.* 2. *If a particular proposition be false, the universal must be false,*

* A affirms, E denies, but both in a general sense;
I affirms, O denies, but both in a particular sense.

but not on the contrary. 3. *Subaltern propositions, whether universal or particular, may sometimes be both true, and sometimes both false.*

4. Two propositions differing both in quantity and quality, are *contradictories ;* as,

A—All planets are inhabited.
O—Some planets are not inhabited.

These can never be both true or both false at the same time.

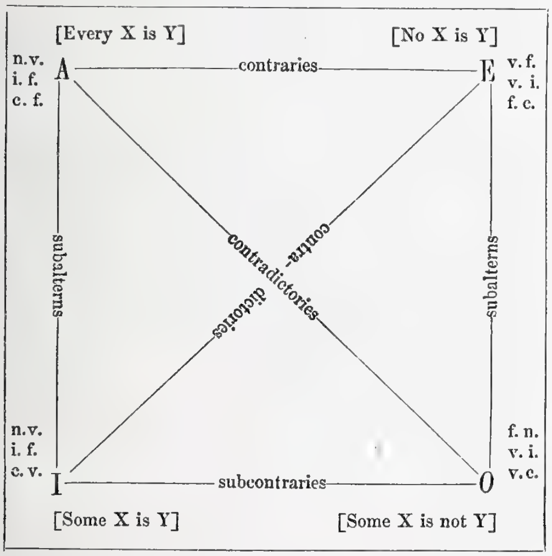
As the truth or falsity of a proposition, supposing the quantity and quality to be known, depends on the *matter*, the following rules may be observed on this subject:—

1. In *necessary* matter, all affirmatives are true, and negatives false; as, "*All* (or *some*) heavy bodies gravitate towards the earth." Here the corresponding negatives, either universal or particular, would be false.

2. In *impossible* matter, all negatives are true and all affirmatives false; as, "Peninsulas are *not* surrounded by water," (meaning either *all* or *some*). Here the corresponding affirmatives, both universal and particular, would be false; because it is *impossible* that a peninsula *can* be surrounded with water.

3. In *contingent* matter, all universals are false, and all particulars true. A poetical talent, for instance, is neither impossible nor necessary, but contingent; therefore the particular propositions, "Some men are poets," and "Some men are not poets," are both true; but the corresponding universals, "All men are poets," or "No men are poets," would, in this contingent matter, be both false.

We subjoin as a logical curiosity, rather than as serving any very useful purpose, the following scheme of these relations, from the work of Archbishop Whately, in which the letters X and Y stand for any subject and predicate; the initials *n*, *i*, *c*, for *necessary*, *impossible*, and *contingent*; *v* for *verum* (true), and *f* for *falsum* (false):—



Any significant terms, as *man* and *mortal*, *star* and *inhabited*, *tree* and *fruit-bearing*, may be substituted for the symbols X and Y, in the above scheme; and on the meaning or relation of these terms, *i. e.*, their agreement or disagreement, wholly or in part, the truth or falsity of each proposition will depend.

"By a careful study of the above scheme," says Whately, "bearing in mind and applying the rules concerning *matter*, the learner will easily elicit all the maxims relating to 'Opposition,' as that, in the Subalterns, the truth of the Particular (which is called the *subalternate*) follows from the truth of the Universal (*subalternans*), and the falsity of the Universal from the falsity of the Particular; that Subalterns differ in *quantity alone*; Contraries, and also Subcontraries, in *quality alone*; Contradictories in both: and hence, that if any proposition is known to be true, we infer that its Contradictory is false; if false, its Contradictory true," &c.

Really, however, these are subjects on which neither rules nor schemes are required, except to explain the meanings of the logical terms employed. It is perfectly manifest to common sense that, if any proposition be true, neither its contrary nor its Contradictory can be so; and canons and axioms are superfluous to teach us that, if *all* worlds are inhabited, *some* worlds are inhabited—a principle unfolded in the language of the schoolmen by the somewhat perplexing circumlocution, that "in subaltern propositions, whether affirmative (A and I) or negative (E and O), the truth of the Particular follows from the truth of the Universal!" This we must candidly admit to be nothing but elaborate trifling.

CONVERSION OF PROPOSITIONS.

This is a subject of greater practical importance. Conversion is of two kinds, Simple and Illative. A proposition is said to be *simply* converted, when its Terms are merely *transposed*, i.e., when the Subject is made the Predicate, and the Predicate the Subject. Thus, "All men are mortal beings," is *simply* converted by saying, "All mortal beings are men," which is not true. *Illative* conversion, on the other hand, is when the subject and predicate are made to change their places with preservation of the truth, or rather, when the truth of the *Converse* is implied by the truth of the *exposita*, or proposition given. This is the only kind of conversion employed for logical purposes; and may be practised with constant certainty (by simple conversion) in all universal negatives (E), and all particular affirmatives (I). Thus, if we say (E) that "No brute is a rational animal," it follows, by *simple* conversion, which is, in this case, *illative* or *inferential*, that "No rational animal is a brute;" or if we say (I) that "Some planets are inhabited worlds," this implies the truth of the converse, that, "Some inhabited worlds are planets."

Now, it belongs to the *science* of logic, properly so called, to inquire and explain how it happens that some propositions can thus be *illatively* converted by simple conversion, and others not. The explanation is connected with the question of *distribution of terms*—a point which was sufficiently discussed in our analytical outline (Chap. III. p. 253). We may, however, remind the reader, that one of the terms is said to be distributed when it is completely exhausted, or applied in the whole extent of its meaning, in respect of its agreement or disagreement with the other term. Thus, when we say, "Man is a mortal being," the term *man* is clearly exhausted or *distributed* in its agreement with *mortal being;* for this may be said of "all men," and such is actually implied in the proposition itself. But here the predicate "mortal being" is not a *distributed* term; we do not say that man is the *only* mortal being—this is not even implied in the form of the expression at all, and hence we are not authorized to say (by a case of simple conversion) that "All mortal beings are men."

The proposition thus analysed, and which we have shown to be incapable of illative conversion by simply transposing the terms, belongs to the class of Universal Affirmatives (A). Archbishop Whately affirms that no propositions of this class are capable of illative conversion; but we have already expressed our opinion, that in some of them the Predicate is really distributed, as, "Romulus was the first king of Rome," "The Chaldeans were the earliest astronomers," "Newton was the greatest of philosophers," "The monks were the custodiers of literature in the dark ages." It cannot be denied that, in each of these propositions, the subject and predicate may change places with preservation of the truth; the conversion is illative or inferential; the truth of the converse is implied in the truth of the exposita; the predicate, in fact, is distributed by being in the superlative degree, or limited by the definite article, as perfectly agreeing with the subject, and with that only.

With reference to class A, we may therefore lay it down as a general rule, that "Universal Affirmatives cannot be converted illatively (inferentially), except when the predicate is limited by the superlative degree, or by the definite article, or one of the demonstrative pronouns, so as to agree *with the subject only*, or when the predicate is merely an exact definition of the subject."

With reference to class E, or Universal Negatives, we have

already remarked that they admit of illative conversion. This will be found to arise from the fact, that, in such propositions, the predicate is always distributed. Thus, in the proposition, "No fool is a philosopher," the term *fool* is denied of the whole class of philosophers. The term *philosopher* is therefore distributed, and hence we may convert the proposition illatively, "No philosopher is a fool."

Particular Affirmatives (I) likewise admit of illative conversion, because, in propositions of this class, neither of the terms is distributed, and therefore, when converted or transposed, they remain in the same relation towards one another. Thus, the proposition, "Some great men are great sufferers," is equally true when converted, "Some great sufferers are great men." Here, in the converse, or second proposition, the partitive *some* is put before "great sufferers;" and this is what is really implied, though not expressed in the first, for nothing is stated in that proposition to indicate that "some great men" constitute *the whole class* of "great sufferers." The terms of the second proposition are therefore exactly equivalent in this case to those of the first. In class O, or Particular Negatives, the distribution of the terms is exactly the reverse of class A—the subject is never distributed, the predicate always; and therefore, when the terms are transposed, their meaning, or extent of meaning, is altered. Illative conversion, consequently, cannot be performed in this case by simple transposition of terms. We may say, "Some mammalia are not quadrupeds;" but it by no means follows that "Some quadrupeds are not mammalia." Or, to take a more self-evident case, though "Some men are not poets," it does not illatively follow that "Some poets are not men." The logical reason of this will be obvious from what has been already stated in reference to the former cases. When we say "Some men are not poets," the predicate "poets" is denied of *some* men, not of all men; but when we say "Some poets are not men," the term "poets," which is now the subject, is excluded from the whole class of men.

The result is, that in A and O (excluding the exceptional cases under A), the terms cannot be transposed without changing their meaning. When "all men" becomes "some men," or "some poets" becomes "all poets," this is not a mere transposition, but a positive changing of the terms. For, as Whately justly remarks, "there is not a *mere transposition* of the terms, but a *new term* introduced, when a term which was undistributed in the *Exposita*, is distributed (or taken universally) in the Converse." In E and G this can never occur, as both terms are distributed in E, and neither in G, so that in these cases only can they be simply converted *illatively*, i.e., without changing their meaning.

Conversion per accidens, and contra-position.—Propositions in A that cannot be simply converted illatively, may be converted by *limitation*, or, as logicans express it, *per accidens*. Thus, although the proposition, "All quadrupeds are animals," cannot be converted by mere transposition of the terms without producing the absurdity, "All animals are quadrupeds," yet the conversion may be rendered illative by *limiting* the term *animals*, so as to express in the converse exactly what it means in the exposita. "All quadrupeds are animals," means, when fully developed, "All quadrupeds are *some* animals;" and this admits of illative conversion, "*Some* animals are *all* quadrupeds," or "*Some* animals are quadrupeds." Propositions of the class A (excluding the exceptional cases) can therefore be converted illatively only by changing the *quantity*.

But this rule does not apply for the conversion of propositions in O. For example, "Some men are not poets," is a particular negative, in which the predicate *poets* is distributed. Let us, then, transpose the terms, while simply changing the quantity, and this will give, "No poet is a man," which is not an equivalent proposition, but a positive untruth. Illative conversion is effected in such cases, by what is called *contra-position*, that is, by making the negative a part of the predicate, and thereby changing the *quality* of the proposition. Thus, "Some men are *not-poets*" may be considered a Particular Affirmative (I), or may be regarded as another way of saying, "Some men are *destitute-of-poetical-genius*;" and, as neither of the terms is now distributed, this may at once be simply converted into "Some-who-are-not-poets are men."

Hence the following rules for illative conversion of propositions:—1. Universal Negatives (E) and Particular Affirmatives (I), admit of illative conversion by simply transposing the terms. 2. Universal Affirmatives (A), by simply changing the *quantity*. 3. Particular Negatives (O), by making the negation a part of the predicate, and thereby changing the *quality*.

COMPOSITION OF PROPOSITIONS.

We explained in last chapter the division of Propositions according to—I. Substance; II. Quantity; III. Quality. Having now discussed the Opposition and Conversion of propositions, subjects which relate to the distinctions of Quantity and Quality, we shall proceed to the fourth principle, or manner of dividing them, namely, according to their Composition.

IV. Propositions, according to their *Composition*, are divided into Single and Compound. A *single* proposition is that which has only one subject and one predicate; but if it has more than one subject, or more than one predicate, it is called a *compound* proposition, and really contains within itself two or more propositions.

1. Hitherto we have treated only of single categorical propositions. *Single* propositions are further divided into Simple and Complex. A *simple* proposition is one whose subject and predicate are single terms; as, "Gold is precious," "Every thought is recorded," "No crime is unpunished." A *complex* proposition is one of which the subject or predicate, or both, are complex terms; as, "Honesty is better-than-policy," "Virtuous-intentions are a consolation-in-failure," "No-frail-child-of-mortality is capable-of-rising-to-perfection." Even propositions of the following form are merely complex, not compound; "Alexander, *who conquered the world*, failed to conquer himself;" for this proposition may be written in regular form, "Alexander-the-conqueror-of-the-world was unable-to-conquer-himself."

2. *Compound* propositions, as already stated, are those which have two or more subjects or predicates, or both, and thus contain more than one proposition, either expressed or implied. These are divided into six kinds (some of which have been already noticed as distinct from categorical propositions), namely, Copulative, Disjunctive, Conditional, Causal, Relative, and Discretive.

(*a.*) *Copulative* propositions are those which have more than one subject or predicate, connected by affirmative or negative conjunctions; as, "Disease and death are the scourges of humanity," "Man courts danger, and even defies death, to gratify his avarice and ambition," "Neither love of life nor fear of death is stronger than the passion for glory." Each of these propositions may evidently be resolved into two or more; as, "Disease is the scourge of humanity," "Death is the scourge of humanity." The second example given above may even be resolved into four distinct propositions. Those propositions which cannot be thus resolved, though two or more ideas be coupled by conjunctions, either in the subject or predicate, are not copulative, but complex; as, "Three and six make nine," "Vanity and pride are different qualities," "Merit and success do not always meet," "The British parliament consists of Lords and Commons."

The truth of copulative propositions depends on the truth of the parts of which they are composed, when divided into separate propositions.

(*b.*) *Disjunctive* propositions are those in which the parts are disjoined or opposed to one another by disjunctive particles; as, "Heat is either a substance or a quality," "The weather is either fair or rainy," "The warrior must either conquer or die, or forfeit his honour."

The truth of *disjunctives*, properly so called, depends on the necessary opposition of the parts. "It either rains or freezes," is not a proper disjunctive, because it may snow or thaw, and neither rain nor freeze.

(*c.*) *Conditional* or *hypothetical* propositions are those whose parts are united by "if," or some such conditional expression; as, "*If* materialism be true, death is annihilation," "*Supposing* the premisses correct, the conclusion is undeniable."

The truth of conditional propositions depends, not on the truth or falsehood of the parts taken separately, but on the connection between them. The first part is called the *antecedent*,

the second the *consequent.* Both of these may be false, and yet the whole proposition be true, as in the first of the examples given above, or the following, "If iron were lighter than water, it would swim." Here the antecedent is false, and it follows that the consequent is false also, yet the proposition, taken as a whole, is true.

(*d.*) *Causal* propositions are compounded of two propositions connected as cause and effect; *e. g.*, "The fogs disappear because the sun is rising," "Age is wiser than youth, for it has more experience," "Man was endowed with reason that he might be a free agent."

The truth of causal, like that of conditional propositions, depends, not on the truth of the parts, but on the truth of the connection between them, as cause and effect. In this case, however, both the parts may be true, and yet, if the one be not the cause of the other, the whole proposition will be false.

There is here an important distinction to be drawn between two meanings of the causal conjunctions, *since*, *because*, &c., and the illative conjunctions, *therefore*, &c. "It is a circumstance," remarks Whately, "which often occasions error and perplexity, that both these classes of conjunctions are often employed to denote respectively *Cause* and *Effect*, as well as *Premiss* and *Conclusion*: *e. g.*, if I say, "This ground is rich, *because* the trees on it are flourishing," or "The trees are flourishing, and *therefore* the soil must be rich," I employ these conjunctions to denote the connection of *Premiss* and *Conclusion;* for it is plain that the luxuriance of the trees is not the cause of the soil's fertility, but only the cause of *my knowing* it. If again I say, "The trees flourish, *because* the ground is rich," or "The ground is rich, and *therefore* the trees flourish," I am using the very same conjunctions to denote the connection of *cause* and *effect;* for, in this case, the luxuriance of the trees, being evident to the eye, would hardly need to be *proved*, but might need to be *accounted* for."

(*e.*) *Relative* propositions are those in which the parts are joined by such particles as express a relation or comparison of one thing to another; as, "*When* you are ready, (*then*) we shall depart;" "*Where* order reigns, *there* are peace and progress;" "*As* is the sire, *so* is the son."

Such propositions, however, though commonly ranked under this head, are not properly compound, for they cannot be divided into two parts, each forming a distinct proposition; and the same remark might have been made with reference to the class of *Conditionals* or *Hypotheticals*, which these propositions somewhat resemble in structure.

(*f.*) *Discretive* propositions consist of two or more parts, between which a contrast or distinction is asserted by the particles *but*, *though*, *yet*, &c.; as, "Wealth may conduce to pleasure, but cannot secure happiness;" "The Stoic was calm and cheerful, though fortune frowned;" "Vices abound, yet many virtues survive;" "The apostles were uneducated men, yet they enlightened the world."

The truth or propriety of such propositions depends on the truth of both parts, and the existence of something in the one part that stands, or seems to stand, in opposition to the other. Where there is no opposition, the proposition may be perfectly true, but will be absurd and unmeaning; as, "Napoleon, though a Corsican by birth, was a great general;" "The Romans were a warlike people, yet they spoke Latin." These cases are improper and absurd, inasmuch as there is no opposition whatever between the constituent parts. Sometimes, indeed, the opposition may be slight, or even may exist only in appearance, and yet a proposition of this kind will hold good; as, "Some men, though small in stature, are great in mind." Here there is no real opposition, yet there is a contrast suggested between the mind and the body.

We have stated that compound propositions are those which contain more than one proposition, either *expressed* or *implied.* In all the preceding examples, the two constituent propositions are *expressed;* the following are a few examples of cases in which the composition is *implied*, or is less evident:—

1. Virtue alone confers true happiness.

[This contains two propositions—"Virtue confers true happiness," and "Nothing else confers true happiness."]

2. Protestants worship none but God;

[Which may be resolved into these—"Protestants worship God," and "Protestants worship no other being."]

3. Pain is the greatest affliction;

[Equivalent to two propositions—"Pain is a great affliction;" "No other affliction is so great."]

4. Cadmus was the first to teach the use of letters;

[Or, "Cadmus taught the use of letters," and "No other person taught the use of letters before him."]

In all these cases, the two distinct meanings or *judgments* into which we have resolved each of the propositions, is clearly implied. Language abounds in such abbreviations, highly convenient in practice, but under which fallacies often lurk; and these it is the province of logic to expose, by taking what is compound to pieces, and showing the entire proposition in its full meaning and import.

PART III.—REASONING AND SYLLOGISMS.

We now come to the third part of Logic—that which treats of Reasoning and Syllogisms. We have seen that the result of the mind, acting in its *first* operation, Perception, is a simple idea, and that the expression of this idea, in one or more words, is called a term. Ideas and terms, with the various divisions of nameable things and relations into their *summa genera*, formed accordingly the first part of this synthetical treatise. We have seen also that the result of the mind, acting in its *second* operation, Judgment, is the perceiving the agreement or disagreement of two ideas, and the expression of this agreement or disagreement in words, namely, the Proposition, is naturally the subject of the second part of Logic, which we have just concluded. The result and process of the mind, acting in its third operation, Reasoning, is the seeking and perceiving the agreement or disagreement of two ideas, *by a comparison of each with a third;* and this result and process, whereby we infer what is less known from what is more obvious, is termed, in common language, an *argument*, which, when logically developed, becomes a *syllogism.* The *syllogism*, therefore, or *reasoning developed*, constitutes the third part of Logic, to which we now proceed.

NATURE AND PARTS OF A SYLLOGISM.

In comparing two ideas, we are sometimes able to pronounce at once whether they agree or disagree; but often we require to take an intermediate step to perceive their agreement or disagreement. The expression of this perception in words is termed in both cases a proposition; but in the former it is the result of the Judgment; in the latter, of Reasoning. In the *act* of the mind termed Judgment, any two given ideas are compared directly; in the *process* of Reasoning, each is compared with a third. In the latter case, if both agree with the third, they are said to agree with one another, or the one is affirmed of the other; if the one agrees and the other disagrees with the third, they are said to disagree with one another, or the one is denied of the other; if both disagree with the third, they may either agree or disagree with each other, and therefore in this case the comparison does not lead to any result.

The necessity of seeking a third idea to constitute the standard of comparison between two other ideas—in other words, the necessity of reasoning—arises from the limited nature of the human faculties. It may be presumed that the Deity never reasons. This process consists in passing by successive steps to a conclusion, which, to an omniscient being, must be self-evident. It somewhat resembles that process by which, in comparing the dimensions of two objects, and finding that we cannot do so directly, we make use of a third, as a foot-rule or yard-measure, and applying this standard to each, we decide as to their relative magnitude.

Thus, if the question be, whether the celebrated Howard deserves to be honoured—here, there are two ideas for comparison, that of the "celebrated Howard," and that of "deserving to be honoured." A person ignorant of the life of Howard might not be aware that he had any claim to distinction, but

let him be informed that Howard was a practical philanthropist; and then, in this third idea, that of "practical philanthropist"—a character which all will admit to *agree* with the title to be honoured—a link of connection is immediately established between the two original ideas involved in the question; and each of the latter is compared with the former, thus:—

Practical philanthropists deserve to be honoured;
Howard was a practical philanthropist;
Therefore Howard deserves to be honoured.

In ordinary language or reasoning, it would be sufficient to say, "Howard was a practical philanthropist, and therefore deserves to be honoured." This would be properly termed an *argument;* but, in its full development, it takes the form above given, and then it is termed a *syllogism.*

A syllogism, therefore, consists of three propositions; and these three propositions are made up of three ideas or terms, variously joined, two by two, in such a manner that the third proposition is inferred from the first and second.

The names of the different parts of the syllogism have been already explained in our analytical outline. In entering again upon this department, however, to give a synthetical and more comprehensive view of the subject, these must be briefly recalled to the reader's mind:—

1. The two propositions from which the third is inferred, are termed the *premisses;* that which is inferred from them, the *conclusion.*

2. The three ideas or terms, two of which are variously joined in each of the three propositions, are named respectively the *major*, the *minor*, and the *middle* term.

3. The subject of the conclusion is the *minor* term, and the predicate of the conclusion is called the *major,* as being generally of larger extension than the *minor.*

4. The major and minor terms are called the *extremes.*

5. The *middle term* is the third idea, occurring in each of the two premisses, and forming the connecting link between the major and minor terms.

6. The *major premiss* is that proposition in which the *middle* is compared with the *major term;* the *minor premiss* that in which the *middle* is compared with the *minor term.* In other words, the *major premiss* is that which contains the *predicate* of the conclusion; the *minor premiss,* that which contains the *subject* of the conclusion.

DIVISION OF SYLLOGISMS.

Syllogisms are divided into different kinds, according to—1. The nature of the conclusion; and 2. The position of the middle term.

1. According to the nature of the conclusion, or that of the question* to be proved, Syllogisms are divided into Universal-Affirmative, Universal-Negative, Particular-Affirmative, and Particular-Negative—the conclusions, in each of these cases, being propositions of the classes denoted respectively by A, E, I, O.

In a Universal-Affirmative syllogism, one idea is proved to *agree universally* with another, and may be *universally affirmed* of it: as.

Every virtue conduces to happiness;
Patience is a virtue;
Therefore patience conduces to happiness.

In a Universal-Negative syllogism, one idea is proved to *disagree universally* with another, and may therefore be *denied* of it *universally;* as,

No human being is perfect;
All philosophers are human beings;
Therefore no philosophers are perfect.

Similar illustrations might be given of *Particular*-Affirmative and *Particular*-Negative syllogisms. In the meantime, we may state that the validity of all pure categorical syllogisms, whether Universal or Particular, rests on the following axioms or canons:—

* "Every Argument consists of two parts; that which *is proved;* and that *by means of which* it is proved. The former is called, *before* it is proved, the *question; when proved,* the *conclusion* or *inference.*"—*Whately.*

Axiom 1. If two terms agree with one and the same third, they agree with each other.

Axiom 2. If one term agrees and another disagrees with one and the same third, these two disagree with each other.

It is evident that on the former of these axioms rests the validity of *affirmative* conclusions; on the latter, of *negative.*

RULES OF THE SYLLOGISM.

The rules of pure categorical syllogisms, founded on the above axioms, are these:—

Rule I.—*The middle term must be distributed, or taken universally,* ONCE AT LEAST, *in the premisses, i. e., by being the subject of an Universal, or Predicate of a Negative;* for if the middle term be taken twice particularly, then it may be taken for two different parts or kinds of the same universal idea, in which case the subject of the conclusion is compared with one of these parts and the predicate with another, so as to leave it undetermined whether the subject and predicate agree or disagree. Thus, in the following example:—

Some steel is magnetic;
Saladin's sword was of steel;
Therefore Saladin's sword was magnetic.

Here the middle term, *steel,* is not distributed either in the major or minor premiss. The subject of the conclusion, *Saladin's sword,* is stated in the minor premiss to be *of steel* (that is, of *some* steel); and in the major premiss it is only affirmed that *some* steel is magnetic; so that the term *magnetic,* which is the predicate of the conclusion, may really be affirmed of a different kind of steel from that which is affirmed of the subject, *Saladin's sword.* It cannot be inferred from the premisses, therefore, that Saladin's sword was magnetic. The fallacy in this example is obvious; but it is less so in cases where the partitive *some* is not prefixed to the middle term, although it may be actually used in a particular or partitive sense, as, "Food is necessary to life."

When the subject of the conclusion refers to one part of the middle term, and the predicate to another, the case is precisely similar to that of an *ambiguous* middle term—a case in which there are in reality two middle terms in *sense,* though but one in *sound;* as,

Rulers are useful for drawing straight lines;
Magistrates are *rulers;*
Therefore magistrates are useful for drawing straight lines.

Here there are evidently two middle terms; the word *rulers* in the *major* premiss being used in a totally different sense from that which it bears in the *minor;* and therefore the subject and predicate of the conclusion are compared with two different things. The case is precisely the same when the middle term is *particular* in both premisses; in the one premiss one thing is spoken of, and in the other another.

But if the middle term be distributed, or taken universally, in *one* of the premisses, this is sufficient, since, if one *extreme* has been compared to a *part* of the middle term, and the other to the whole of it, both extremes must have been compared to the same; thus, if "*All* men are mortal," and if "*Kings* are (some) men;" then it follows that *kings* must agree with whatever agrees with *all men;* and hence we infer that "Kings are mortal."

Rule II.—*The terms in the conclusion must never be taken more universally than they are in the premisses*; (or, more precisely), *No term must be distributed in the conclusion which was not distributed in one of the premisses;* thus,—

All trees are vegetables;
Shrubs are not trees;
Therefore they are not vegetables.

Here, in the major premiss, the term *vegetables* is not distributed, being in this case the predicate of an affirmative proposition. In the conclusion, however, the same term is distributed, being the predicate of a negative. Now, it is evident that Universals cannot be inferred from Particulars. Indeed, by distributing *vegetables* in the conclusion, a fourth

term is introduced; for nothing has been said in the premisses of *all* vegetables.

This distribution of a term in the conclusion which is not distributed in one of the premisses, is termed an *illicit process.* It will be observed that the preceding example involves an illicit process of the *major term, i. e.,* of the predicate of the conclusion. The following is an illicit process of the *minor term,* or subject of the conclusion:—

> Whatever is related in romances is fictitious;
> History is given in some romances;
> Therefore history is fictitious.

Rule III.—*From two negative premisses nothing can be concluded;* for in this case the middle term is merely pronounced to disagree with both extremes, and therefore it does not afford the means of comparing them with one another. Thus, from the premisses,—

> No free agent is irresponsible,
> No slave is a free agent—

nothing whatever can be inferred; whereas, if we stated, as the major premiss, that "free agents are responsible," making the proposition affirmative, then it would follow as a valid conclusion, that "No slave is responsible."

Rule IV.—*A negative conclusion cannot result from two affirmative premisses.* This is obvious from the fact, that two affirmative premisses merely assert the agreement of *both* extremes with the middle term Hence we can only infer the *agreement,* not the *disagreement,* of these extremes; and this agreement can only be expressed by another *affirmative* proposition.

Rule V.—*If one premiss be negative, the conclusion must be negative;* for, by the negative premiss, the middle term is pronounced to disagree with one of the extremes, while, by the affirmative premiss, it is declared to agree with the other. Hence, the two extremes themselves must disagree, and this disagreement can only be expressed by a *negative.*

Rule VI.—*If either of the premisses be particular, the conclusion must be particular.*

This rule may be demonstrated by strictly mathematical reasoning, from the axioms and rules already given. For, by Rule III., nothing can be inferred from two negative premisses. The premisses, therefore, must either be both affirmative, or one affirmative and the other negative.

Case 1.—Let us consider, in the first place, the case in which both premisses are affirmative. In this case, by Rule IV., the conclusion must be affirmative; and let us suppose, for the sake of argument, that this conclusion is not particular, but universal. To render it such, the subject of the conclusion or minor term must be distributed. But again, by Rule II., no term must be distributed in the conclusion which was not distributed in one of the premisses. The minor term must therefore, on this supposition, be distributed in the minor premiss. But it is assumed that both the premisses are affirmative; and it has already been proved to hold as a *general* principle, that the predicates of affirmative propositions are never distributed. The minor term is therefore the subject, not the predicate of the minor premiss, and hence it follows that this premiss is universal. The other premiss must therefore be particular, it being the assumption on which we proceed, that *one* of the premisses is so. But, in particular affirmatives, neither of the terms is distributed; in universal affirmatives, only one of the terms. The *minor* is therefore the only term distributed; and hence it follows that the middle term is particular in both premisses; but, by Rule I., the middle term must be distributed *once at least* in the premisses; hence the assumption, that in this case the conclusion may be universal, with one of the premisses particular, leads to a *reductio ad absurdum.*

Case 2.—Let us now suppose that one of the premisses is affirmative, the other negative, and let us, for the sake of brevity, adopt the following symbols:—

A—Affirmative premiss.	X—Major term.
B—Negative premiss.	Y—Middle term.
C—Conclusion.	Z—Minor term.

Since, by hypothesis (or supposition) one of the premisses (B) is negative; it follows, from Rule V., that C is negative.

Now, let us assume (as in Case 1), that with one of the premisses particular, the conclusion may be universal, and let it be our object to show, by means of the *reductio ad absurdum,* that this must involve a contradiction, and therefore cannot take place.

On this supposition, Z, the subject of C is distributed (by the definition of Universals). But it has been proved that C is negative; therefore X, the predicate of C, is also distributed. Hence, by Rule II., both X and Z are distributed in the premisses. Now, in affirmative propositions, the predicate is not distributed; hence, neither X nor Z can be the predicate of A. Its predicate must therefore be Y, which is in this case not distributed, being the predicate of an affirmative. But this affirmative, A, is Universal, for it has been shown that its subject must either be X or Z, and both of these are distributed. The negative premiss, B, must therefore be particular, for by hypothesis one of the premisses is so. The subject of B is therefore not distributed (by the definition of Particulars), and hence it can neither be X nor Z, but Y. The middle term, Y, is therefore distributed in neither of the premisses, A, B; so that by Rule I., we arrive at the same result as in the first case, namely, a *reductio ad absurdum.*

It follows that in no case, therefore, if one of the premisses be particular, can the conclusion be universal. Q. E. D.

Rule VII.—*From two particular premisses nothing can be proved.*

For, as in demonstrating the last Rule, either the premisses must be both affirmative, or one affirmative and the other negative.

Case 1.—If both premisses are affirmative, then, as they are both particular also (by hypothesis), it follows that none of the terms is distributed. But, by Rule I., the middle term must be distributed *once,* otherwise nothing can be proved.

Case 2.—If one of the premisses be affirmative and the other negative, then, as the premisses are both *particular* (by hypothesis), the only distributed term is the predicate of the negative premiss. But in this case, by Rule V., the conclusion (if any can be drawn) is negative; and this will therefore distribute its predicate, which (by definition) is the *major* term. Again, by Rule II., no term must be distributed in the conclusion, which was not distributed in one of the premisses. The major term must therefore be distributed in the major premiss. But we have seen that in the premisses only one term is distributed; this must be the major term, and therefore the middle term remains undistributed in both premisses, from which, as in Case 1, it follows that nothing can be proved.

CASE 1.

Major premiss.—Some X is Y,	or	Some Y is X.
Minor premiss.—Some Y is Z,		Some Y is Z.

CASE 2.

Major prem.—Some Y is not X,	or	Some Y is not X.
Minor prem.—Some Z is Y,		Some Y is Z.

By substituting any significant terms for these symbols, the reader will readily perceive that nothing can be deduced from the premisses.

ON THE PHYSICAL FACTS CONTAINED IN THE BIBLE COMPARED WITH THE DISCOVERIES OF THE MODERN SCIENCES.

By MARCEL DE SERRES.

ARTICLE II.

(*Concluded from page* 138.)

ONE circumstance may well surprise us, and that is, to find in the Bible mountains distinguished into two classes, very nearly in the same manner as they are distinguished by science into primitive and secondary. Thus, in the 104th Psalm, a com-

position of incomparable poetical beauty, the prophet gives us an idea of the formation of the earth; he represents it to us as still covered with the waters of the deep as with a garment. The waters stood above all the mountains, but many of these eminences became elevated, and rose above their level; the waters then retired and fled. New mountains then appeared, and valleys and plains, the lowest parts of the globe, were formed at their feet. Two principal epochs, then, must have been in the mind of the prophet, from the time of the rising up of the heights which appear on all parts of the globe; these two epochs correspond to the formation of primitive and secondary mountains.

Thus the prophet (Proverbs viii. 25), in speaking of the elevation of mountains and hills, says that these events, which have singularly modified the relief of the globe, had their separate eras. Further, in the 97th Psalm, Scripture represents the mountains to be melting like wax, nearly as those might have done who had seen the rocks of Auvergne or Cantal in a fluid state, or the basalt of the Giant's Causeway melted like water.

The Bible then represents to us the mass of mountains issuing from the bosom of the earth at the voice of God, and rising above plains and valleys. It gives us an account of the process of their elevation, in terms which might have been used by a poetical geologist. "The mountains," is the enthusiastic language employed—"the mountains rise above the deep, and the valleys sink to the place which thou hast chosen for them."

Reference is even made to the force by which they have been elevated; it is represented as proportionate to the elevation to which their eminences have been raised, being most powerful when employed in elevating the mountains properly so called, and weaker when its efforts were limited to the rising of the hills above the valleys. In its figurative style, it compares the elevation of the former to the skipping of rams, and that of the second to the leaping of lambs.

The earth is thus represented as being soft as clay, at the time of these great events. It is then described as having assumed a new face, and having adorned itself with a new garment, a sort of allusion to the sedimentary deposits with which the superficial crust became covered.

When Scripture speaks of the electric fluid, it represents it to us as resounding throughout the whole space of the heavens, and causing its lightnings to shine even to the remotest parts of the earth. After their light the thunder roars, and its rolling sound is heard. The noise of the thunder, it says, announces that the wrath of God is about to fall on all that aspires to elevate itself. Scarcely has the sound been heard, when the bolt has already struck. Thus God breaks forth in the voice of his thunder; he who works such great and mighty wonders, traces his path in the thunder, and regulates the course of the tempests.

Such is the idea which it gives us of this phenomenon, the rapidity of which is even greater than that of light. In fact, according to Mr. Becquerel's experiments on the rapidity of electricity, this fluid traversed ninety thousand leagues in a second. Its velocity is therefore greater than that of light, which is only at the rate of eighty thousand leagues in the same space of time.

The electric fluid not only exhibits the greatest velocity, but it enters in considerable quantity into the composition of the molecules of bodies. The quantity is indeed so immense, that the imagination is startled at it. The elements of a simple molecule of water appear to contain eight hundred thousand charges of an electric battery of eight jars two decimetres (about eight inches) in height, and six (about two feet) in circumference, obtained by thirty revolutions of a powerful electrical machine. If the quantity of electricity accumulated in the elements of a gramme (about $15\frac{1}{3}$ grains) of water, happened suddenly to be set free in the middle of any building, the building would instantly be blown in pieces.

This power, compared with which steam is as nothing, whether we consider it as an extremely subtile matter, or rather as the result of a vibratory movement impressed on the ether, is only employed by nature in maintaining the combinations and molecular constitution of bodies. We ought not, therefore, to be surprised at the importance which Scripture assigns to thunder and lightning, which is one of the not least curious of its effects. There are few natural phenomena in which electricity does not act a part, and which are not more or less dependent upon it. How can it be otherwise, since each material molecule appears to be endowed, not only with a certain quantity of heat and light, but also with electricity?

Genesis is not less exact when it calls our attention to the living beings which, by turns, have animated and embellished the surface of the earth. It delineates their succession, it teaches us that they have appeared in distinct generations, and in direct relation to the complexity of their organization. We are surprised to find such a law written in the Bible, a law equally to be traced in indelible characters in the bowels of the globe. This fact, clearly expressed in a Book which has existed from so old a date, has, notwithstanding, been known to us only for half a century. To the general idea thus connected by Moses with the appearance of living beings, this great legislator adds details, the accuracy of which is not less evident in our opinion, although assertions to the contrary have been made by many illustrious naturalists. According to him, terrestrial vegetables preceded the animals which inhabit the dry and uncovered land. In this particular, chemistry confirms the assertion of the sacred writer; but geological observations seem to be opposed to it. Accordingly, certain modern natural philosophers, far from admitting it as real and satisfactory, have regarded it as a manifest error. The question is to determine whether these observations are as conclusive as they are supposed to be, and if, according to the nature of things, vegetables must not have appeared before animals.

The researches by means of which it has been supposed possible to prove that vegetables have not preceded beings endowed with motion, are far from authorizing the inference wished to be deduced from them. In fact, while terrestrial vegetables appear in great numbers in the transition formations, this is far from being the case with animals. Only a few individuals of the lower classes of the animal kingdom have been discovered in them; up to the present time, the number does not exceed six species at most. And yet the most active researches have been made in all parts of the world to discover a greater number. But even although these beings had been observed in the same terrestrial strata, this would not have been a proof that they lived simultaneously. We are unacquainted with the time which may have been necessary for the precipitation of these ancient strata, as well as for their consolidation. Hence plants, although anterior to such or such species of animal, may have been imbedded along with it in the same order of deposit, the latter having required more or less considerable intervals of time for its formation.

There is, therefore, more or less uncertainty with regard to the simultaneity of the period of the appearance of vegetables and animals, if we suppose that both were interred in formations of the same age. It is far from being demonstrated, that terrestrial plants are not found in strata more ancient than those in which we discover animal species. Geological facts do not, therefore, contradict the progression indicated by the author of Genesis, in regard to the appearance of different living beings. This assertion of Moses is a geological consequence of high importance, confirmed by the observation of facts, as has been remarked by one of the greatest natural philosophers of our day.

This consequence is, moreover, a rigorous, because it was a necessary one. Terrestrial animals derive their food from vegetables, even such of them as subsist on living prey. By devouring herbivorous species, they, in fact, support themselves by means of the herbaceous matter which these latter had assimilated and converted into their own substance. If, then, the herbivorous must have existed before the carnivorous races, to which they were to serve as food, both the one and the other must have been preceded by the plants which were to afford them the means of growth and development. By a consequence of the same kind, we may admit that omnivorous animals must have appeared last among living beings.

This conclusion, at which we arrive by a process of simple reasoning, is confirmed by observing the strata of the globe.

It is remarkable to find this fact recorded in Genesis, written at least 3500 years ago. This book admits, in like manner, the gradual appearance of vegetables. It makes them commence with the least complicated species, to which succeed herbs, then shrubs, and finally trees. Posterior to all animals, the sacred writer places the arrival of man, who crowns and terminates the great work of Creation.

Naturalists who have occupied themselves with this question, have not examined it with the view of justifying the author of Genesis; and this very consideration gives their opinion greater weight, for it has been forced on their minds by positiveexperience.

It isto this part of the subject that Herschel's beautiful thought is more particularly applicable. Struck with the relations which the sciences are every day contracting with revelation, he says, "that all human discoveries seem to be made only for the purpose of confirming more strongly the truths come from on high, and contained in the sacred writings." This illustrious astronomer has seen in this agreement the most valuable triumph and most noble conquest of intelligence.

This scientific fact may be regarded even in a still more important light. It indicates that the author of Genesis has had just reason to look upon man as the last that appeared of living beings, and to regard him as the limit and completion of the creation. If plants have preceded herbivorous animals, because the latter must derive from these all that serves them for nourishment, herbivorous animals must, in like manner, have appeared before the carnivorous species. In truth, without the herbivorous races, the carnivora must have died of hunger. For similar reasons the omnivorous, or such races as live both on vegetables and animals, must have made their appearance at a later period. Accordingly, man, who is omnivorous *par excellence*, must have appeared last among living beings, since he requires the presence of all kinds of nourishment.

On the other hand, when Scripture speaks of the creation of plants, it makes them vegetate and develop themselves before the appearance of the sun, and under conditions of light, heat, and humidity, different from those under which vegetables now flourish. It has thus disclosed to us, thousands of years ago, an order of things which the fossil botanist has found to exist with great exactness, and which he has endeavoured to explain by causes different from those whose action is now felt. Scripture, therefore, has admitted with reason, that the germination of vegetables commenced before the sun had received the power of shedding his light on the earth; it is thus, by motives not less legitimate and not less real, that it makes plants appear before animals, which they are destined to supply with nourishment. But let us consider whether Scripture has had equal reason for proclaiming the recent appearance of the human species as compared with other living species.

What we have already observed, is in some measure a proof that the arrival of man on earth must have been posterior to that of the greater part of animals, whether vertebrate or invertebrate. Not many serious difficulties can be formed on this point. The examination of fossiliferous strata proves, that the remains of our species do not begin to show themselves till we come amongst diluvial deposits, which are the most recent of those belonging to geological eras. Man has, therefore, formed part of the new generations which have appeared on the surface of the earth; also, the greater part of those with which he has been cotemporary have still their representatives among the living races.

But, man may be recent, even the newest of beings, and yet the date of his appearance may go so far back as the 7500 years which Scripture assigns to him. Is it necessary to suppose with Scripture, that the last arrangement on the surface of the globe is more recent than the last and terrible catastrophe which laid it waste, a catastrophe followed by the renewal of the human race? Would it be reasonable for all ages, all people, and, in particular, our modern schools, to set themselves in opposition to a date which assigns so youthful an age to our haughty race? Assuredly not: geological investigations, the researches of history, and the study of monuments, all concur in demonstrating, not only the recent date of man's appearance, but particularly that of his renovation.

Here, therefore, Scripture is exact and within the limits of truth. The term it assigns to the cradle of humanity, although not very remote from that in which civilization has arrived at a degree of remarkable splendour, is still sufficient to explain and comprehend the various phases of it. We may include in these 7500 years, all that authentic historical traditions have told us respecting the progress of man in the path of civilization.

The Bible has, in like manner, acknowledged the unity of the human species. This truth, for a long time disputed, has been regarded in our own times both by the most illustrious physiologists and most able anatomists as fully established. The intimate acquaintance of both these classes of observers with the proofs which demonstrate it, give the greatest authority to their opinion.

At some future period, not very remote, this question will probably cease to be open to any dispute. In fact, the black men who, by losing ground and going backwards in the path of civilization, have lost in a great measure the beauty of their primitive type, are now returning to the blessings of intelligence, and have established themselves as nations. They show a tendency to remount to the point from which they receded: as the consequence of their progress in knowledge and the improvement of their mental faculties, they will soon recover the type which they had lost. The development of their brain, the necessary consequence of the exercise of their minds, will make them acquire new forms; and soon they will cease to be distinguishable from the white race from which they sprung. With the advance of their intelligence, their language will become purer; their manners will undergo a corresponding improvement; and these men, not long since so debased, both in moral and physical qualities, will become the most manifest proof of the unity of the human species, as proclaimed by the first and most ancient historian.

This primitive unity must necessarily imply a uniformity in the language of mankind, or in the manner of making themselves understood, and communicating their thoughts to each other. The Bible intimates this; and we can go back with it to the precise period when the confusion of languages took place among the nations. A superficial study of the idioms of the primeval races has appeared, at first vew, not very favourable to the idea of their having a common origin; but a more profound examination has shown in what manner all the languages spoken came gradually to differ from each other.

It is not less deserving of attention, that the Bible is the first book in which we find notions of classification, analogous to those which naturalists employ in the study of the different natural bodies. In the 11th chapter of Leviticus, in particular, we find a sketch of a method of distinguishing pure animals from impure, the latter of which the Hebrews were forbidden to eat. God allowed the children of Israel to eat animals which ruminated and had the feet cloven; but they were interdicted from using others. Swine, and even camels, were included in the interdict; the former because they did not ruminate, the latter because they had not their feet divided like oxen and sheep.

Birds of prey were also, according to scripture, impure animals, which the Hebrews were not permitted to use for food. They were allowed to make use only of long-legged species (*Grallæ*, Linn.), and those whose feet were adapted for swimming. They might employ for food all the marine and fresh-water fishes provided with scales and fins; but they were not to eat such as were destitute of these appendages. In this ordination there can be no doubt that a great degree of wisdom is shown: for the animals we now use for food belong to pure species; while, with the exception of the hog, those which Moses regards as impure are, in general, ill-fitted for human consumption. But what is most important to be remarked is, that in this arrangement there can be traced the basis of a natural classification, which is still adopted in the most common systems.

Scripture is not less precise when it turns its attention to the objects of detail relating to living beings. It is, in particular, in delineating the manners of animals, that these writings exhibit an accuracy and conciseness which the greatest naturalists have not surpassed. Its descriptions are so faithful

and so precise, that they cannot be mistaken. Thus it represents to us the lioness couched in her cave, watching with a restless eye the prey about to pass, and waiting with the utmost anxiety on her young whelps. When she perceives the prey, we are told how she darts forth with the rapidity of an eagle, carrying her victim in her mouth to appease the hunger of her young ones. Very different from the young lions, the young ravens wander about from one place to another, oppressed by hunger; they call with loud noise on their mother, who finds her greatest delight in supplying them with food.

It indicates to us, in like manner, the time of gestation and delivery of the hinds and wild goats. These animals are represented as bowing themselves when they bring forth, and uttering sorrowful cries. The wild ass is spoken of as being singularly fierce, incapable of being subdued, and answering not to the voice of him who calls himself its master; free and ranging the mountains as his pasture; his abode is in solitude, and his retreat the desert.

Man, it tells us, cannot subdue the oryx; he cannot force it to remain even for a single night in a stable; still less can he make it submit to the yoke, to open the furrows, and harrow the fertile valleys. Notwithstanding his power, the strength of man is incapable of making this untameable animal assist him in his labours. He cannot make use of it to carry his harvests, or to gather them into his barns.

The delineations of the manners of these animals are extremely true, and are expressed with remarkable conciseness. Such is the case with those the Bible gives us respecting the habits of the ostrich, a bird which it represents as void of affection for its young, which are in its eyes as if they were not its own. Forgetting her offspring, the ostrich leaves her eggs in the earth, and warmeth them in the dust. A foolish and thoughtless mother, she cares not what may become of them; forgetting that the foot may crush them, or that they may be destroyed by the cruel jaws of the tigers of the desert. But when it is the proper time, she raises her wings into the air; trusting to the strength of her legs, she scorneth the horse and his rider.

The description of the horse is not less faithful; the Bible represents it to us as full of strength and vigour, and bounding like a grasshopper. His neck is adorned with a flowing main, and he paweth the earth with his foot. He leaps forward with pride, and goeth forth to meet the armed men. His breathing scatters terror; he mocketh at fear, neither turneth he back from the sword. When the quiver rattleth against him, the glittering spear and the shield, he swalloweth the ground with fierceness and rage. If he hears the sound of the trumpet, he exclaims, let us advance; he smelleth the battle afar off, the thunder of the captains and the shouting.

At the command of the Eternal, Scripture states, the hawk darts into the air, and extends her wings towards the south. At His voice, the eagle rises to the clouds, and places her nest on the top of the mountains. This bird inhabits the hollows of the rock, and dwells in the most inaccessible cliffs of the crag. From these elevated heights the eagle watches her prey; her piercing eyes discover it afar off. When she has seized it, she carries it to her young, who drink its blood. Under the guidance of their mother, the young eaglets soon descend to the places where the carcass lies. Images of death, these birds bear, in some degree, its livery on their plumage.

Scripture often makes mention of the migrations undertaken by so many animals, particularly birds and fishes. It often compares the rapidity of birds of passage, as they cross the seas, to the speed of vessels using their large sails as if they were huge wings. It shows to us the extensive journeys performed by these light inhabitants of the air, their immense numbers, their fatigues, the consequence of their lengthened flight, and the promptitude with which they alight when they reach the end of their journey. Everything, in the delineation of the manners of these birds of passage, is rapid and animated as the movements themselves of the beings which people the aerial ocean.

We have enumerated some of the principal physical facts contained in the Bible; we have endeavoured to show the relations they bear to those with which science has recently made us acquainted. It seems that nothing now remains for us to ascertain. There is, however, one essential point, of which we have omitted to speak, and with this we shall terminate our researches. The Book of Wisdom, after having said that the almighty hand of God made the world out of nothing, adds, that he disposed all things by number, weight, and measure. By this we are led to understand, that we ought to consider natural bodies under three aspects; that is to say, under that of their extent, their weight, and the number of atoms or molecules which compose them. Perhaps it was thus meant to specify the principal modes of regarding bodies, or the principal branches of natural science. Physics would, in this way, be represented by measure, the mathematical sciences by number, and chemistry by weight.

Scripture describes, in a few words, the principal properties of bodies, and how we may sum up their different appearances and different characters. Thus God asks Job where he was when He laid the foundations of the earth, and when He established the measures thereof? where he was when He enclosed the sea with barriers, when it broke forth as a child which comes from the womb of its mother? or when enveloping the clouds as with a garment, He surrounded it with darkness like the swaddling-bands of infancy? Has man ever known the paths of light, or the place of darkness?

The details into which we have entered seem to prove, with some degree of evidence, that the physical truths most essential to the knowledge of the material world, are almost all indicated in the first books of the Bible. They are never, indeed, fully developed, because Moses and his successors were not called upon to write scientific treatises. While speaking of God, and the works which proclaim his power, they have, as if in spite of themselves, allowed some gleams of their superior knowledge to break through. Their object, and almost their sole object, has been to point out their duties to the people they were called upon to direct, and, particularly, to fill their minds with the fear of the Lord. It was sufficient to unveil to them the principal facts of this visible world, to convince them of the wisdom of the Most High, so clearly imprinted on the works he has produced. Explaining them, accordingly, with an admirable conciseness, the greater part of these facts have escaped the notice of the first interpreters of Scripture, who, from inability to comprehend them, have not given to the sacred Books all the importance they now possess in our eyes. Their errors, altogether involuntary, are so much the less to be wondered at, since the Bible contains particulars for which we cannot yet assign a reason in the present state of our knowledge. The constant progress of human science will soon render them intelligible. This is not the least of the advantages of the sciences, nor the least valuable inheritance we can leave to our descendants. They will not forget, more than we, that Scripture is a treasure open to all; and that it is the only book from which those that borrow run no risk of being accused of plagiarism. The ideas which they may draw from it have already belonged to millions of intelligences; but if they understand them better than their predecessors, they will so much the more belong to them, since they shall have been the first to perceive them.

CONCHOLOGY.

CHAPTER V.

TRIBE IV.—ALATA.

Shell provided with a canal, of greater or less extent, at the base of the aperture; the right lip changes its form as the animal progresses towards maturity, and is provided with a sinus near its base.

Genus.—Strombus.—*Linnæus.*

Generic Character.—Shell oblong, subventricose; spire more or less acutely turreted; aperture generally elongated, and in most species with a short canal at its superior extremity, and

PLATE VII.

in some cases having an elongated narrow canal, extending nearly to the apex of the spire; outer lip sharp-edged and entire in the young state, but dilating and thickening with age into an expanded wing, lobate at its superior edge; sometimes with several notches both above and below; but having a well-marked sinus near the inferior extremity or base; this is sometimes very strong, and in other instances almost obsolete; aperture provided with a long, narrow, horny operculum.

Strombus lœvis. Plate IV. fig. 18. Found at Grignon.

Strombus pugilis. Plate IV. fig. 19. Found in the Blue Marls, south of France.

The Strombi inhabit the seas of warm climates. There are many species.

Fossil species occur but seldom; they are met with in the newer formations, above the chalk, in the *Calcaire-grossièr*, Paris, and in a similar formation at Bordeaux. The Tertiary Traps at Vicenza contain two or three species.

Genus.—Pteroceras.—*Lamarck.*

Generic Character.—Shell subturreted, oblong-ovate, subventricose; spire short; body very large, its base terminating in an elongated, generally recurved pointed canal; aperture oblong, its superior extremity extended into a canal, which is sometimes double; outer lip thin, acute at the edge when young, but, in the adult state, thickened, and dilated into a wing shape, its margin provided with a series of digitations or horns, and with a deep sinus near the lower extremity, but not close to the base; outside usually tuberculated, coated by a thin horny epidermis; operculum horny, thick, oblong, rounded above, and pointed below. One or two species have a single horn-shaped process inserted between the basal sinus and the lower canal.

Pteroceras Oceani. Plate IV. fig. 20. Found in the Kimmeridge Clay at Havre and the Jura.

The position of the sinus near the extremity of the outer lip, and it also being digitated, together with the short spire, distinguish the shells of this genus from those of *Rostellaria;* and the lobes and curved canal separate them from the Strombi.

There are but few species of *Pteroceras*, and these inhabit the tropical seas.

The fossil species are rare, and are met with in the rocks of the Oolitic group. The species figured is exceedingly rare, which, with another imperfect example, are the only known specimens. It is from Minchinhampton Common, from the beds of planking.

Genus.—Aporrhais.—*Da Costa.*

Generic Character.—Shell turreted, fusiform; aperture subquadrate, ending above in a canaliculate groove, and below in a slightly twisted beak, which is canaliculate within; the outer lip expanded, and its margin provided with digitated lobes; inner lip broad, with a thick coating of enamel, extending the whole length of the body.

Aporrhais calcarata. Plate IV. fig. 21. Found in the Whetstone pits at Blackdown; the fossil species are only known in the newer formations.

The shells of this genus inhabit the ocean, and are principally European, as none are known to exist south of the Mediterranean.

Genus.—Alaria.—*Morris and Lycett.*

Generic Character.—Shell turreted, winged, and with a caudal extremity; the wing either entire or digitated, sometimes produced into a thickening or varix, destitute of a posterior canal; left wing thin, and never thickened, nor extended upon the penultimate volution; right lip sometimes extended slightly upon the penultimate volution; anterior canal either produced and lengthened, or short.

This genus was formed for the reception of a numerous group of winged fossil shells, which are separated from the true Strombidæ, Rostellariæ, and Pterocerae, by the absence of a posterior channel upon the spire. Another character which well characterises this group of shells is, that the animal, after having formed the right margin of the shell, continued to increase in growth, and (like the species of Murex and Ranella) constructed a second dilated and digitated margin, similar to the first, and generally opposite to it; a character rarely, if ever, found in the recent Pterocerae or Rostellariæ.

Alaria armata. Plate IV. fig. 22. Found in the planking beds of Minchinhampton Common.

Genus.—Hippochrenes.—*Montfort.*

Generic Character.—Shell oblong-ovate; body large; spire of medium length, smooth and taper; aperture long, narrow, ending in a straitened canal, both above and below; outer lip large and much expanded, and but slightly reflected; columella provided with a thick glazing, which usually extends high upon the spire, sometimes beyond its tip.

Hippochrenes macroptera. Plate IV. fig. 23. Found in the London Clay at Hordwell and Highgate Hill.

The shells of this genus are marine, and only occur in a fossil state.

Genus.— Rostellaria.—*Lamarck.*

Generic Character.—Shell turreted or fusiform; spire uniformly longer than the aperture; the superior volutions generally longitudinally grooved, aperture oblong, its upper parts prolonged into an elongated narrow canal, which, in some instances, extends to the apex of the spire, and not unfrequently turns down on the opposite side; base with a more or less lengthened canal, pointed beneath; outer lip in the infant state thin, but becomes greatly dilated with age, entire, or dentated at its lower margin, or digitated; outside covered with a thin horny epidermis; aperture provided with a thick corneous operculum, of an oblong form, rounded at one end, and pointed at the other.

Rostellaria lucida. Plate IV. fig. 24. Found in the London Clay at Highgate Hill.

The sinus close to the pointed canal distinguishes this genus from the genera *Strombus* and *Pteroceras*, these having the sinus remote from the lower canal.

The *Rostellariæ* inhabit the ocean. They are not numerous.

Fossil species are found in the London Clay, the Greensand, *Calcaire-grossièr* of Paris, and in the Tertiary formations of Bordeaux and Italy.

TRIBE V.—CANALIFERA.

Shell with a more or less lengthened canal at the base of the aperture, and of which the right margin does not change its form as the animal advances in age.

Subdivision I.—Shell provided with a permanent varix on the outer lip, and also varices on the spire.

Genus.—Triton.—*De Montfort.*

Generic Character.—Shell ovate or oblong, thick; with interrupted varices, situated at irregular distances, one or two on each volution; spire prominent, and mammillated at the apex; aperture round or oval, terminating above in an ascending canal, and below in an elongated and reflected beak; outer lip thickened, reflected, and generally denticulated within; whole surface covered with a strong horny epidermis, which is frequently provided with a fringe of long ciliated hairs on the outer lip and base of the volutions. Operculum thick and horny.

Triton canaliculatum. Plate IV. fig. 25. Found in the London Clay at Barton Cliff and Muddiford.

The rugose inner lip, and the varices never exceeding two on the volutions, distinguish the shells of this genus from those of *Murex.*

The Tritons inhabit the seas of the East and West Indies and South Seas. The species are but few. Fossil Tritons occur only in the Tertiary formations, in the Crag, London Clay, and Greensand.

Genus.—MUREX.—*Linnæus.*

Generic Character.—Shell oblong, subturreted; spire frequently prominent, with an acute apex; furnished with three or more rough, spinous or muricated varices, frequently digitated or spinous, or with fringed projecting foliations; aperture suborbicular; columella smooth; base with a lengthened canal, sometimes very long, frequently recurved; outer surface protected by a thick horny epidermis; aperture provided with a horny operculum.

Murex cristatus. Plate IV. fig. 26. Found in the London Clay at Highgate Hill.

There is some difficulty in discriminating the Murices. They are distinguished from the *Tritoniæ* by the smooth columella, instead of being rugose, and in always having three varices at least; they differ from *Fusus* and *Fasciolaria* in their general shape, and again in the varices, of which those genera are always destitute; and *Ranella* has but two rows of varices; the general shape and elongated canal remove them from *Recinula;* and the shorter proportion of the spire separates them from *Cerithium*, in which it is invariably longer than the aperture.

The species of this genus are very numerous, and inhabit the seas of almost all countries.

Fossil Murices are tolerably abundant, and occur in the London Clay, Blue Chalk Marls, south of France; the Super-Cretaceous Rocks of Bordeaux and Dax; also in the Cretaceous and Oolitic groups of rocks.

Genus.—TYPHIS.—*De Montfort.*

Generic Character.—Shell subcylindrical, subturreted; volutions provided with numerous cylindrical, pervious processes; aperture suborbicular; beak short, with a closed tubular canal.

Typhis fistulosus. Plate IV. fig. 27. Found in the London Clay at Barton Cliff.

The shells of this genus seem only to be found in a fossil state, and in the newer formations; namely, the Super-Cretaceous rocks of Bordeaux and Dax, &c.

Genus.—RANELLA.—*Lamarck.*

Generic Character.—Shell oval or oblong; subcompressed; with depressed straight or slightly oblique distichous, and frequently spinous varices, situated at intervals of half a volution, forming a continuous longitudinal row on each side; aperture subovate; base canaliculated, and frequently with a small canal above, at the junction of the outer and inner lips; outer lip grooved, with its edge crenated or dentated; inner lip usually rugose, the outside more or less tuberculate, frequently set in small bead-like rows, and generally covered with a thickish olivaceous epidermis.

Ranella Bartonensis. Plate IV. fig. 28. Found in the London Clay at Barton Cliff.

The two lateral rows of varices at once distinguish this genus, as well as their general construction. The only genus with which they may be confounded is *Triton*, and that will be with those very few species, wherein the varices are more remote from each other than half a volution; but attention to the other characters will lead to the distinction.

The Ranellæ are not numerous, and are natives of the East Indian Ocean.

Fossil species are very rare, and hitherto have been found, principally, in the London Clay, the Blue Marls of France, the Super-Cretaceous rocks of Bordeaux, Dax, &c.

SUBDIVISION II.—Shells without a constant ridge on the outer lip.

Genus.—PYRULA.—*Lamarck.*

Generic Character.—Shell thin, pyriform, oblong, ventricose above, somewhat attenuated below, and usually very regular in form; spire short, rounded, and consisting of few volutions; aperture wide, terminating in an elongated, narrow, open canal, wider towards the aperture, and narrowing as it descends; outer lip thin, sharp on the margin, and minutely crenulated; columellar lip tortuous and smooth, and spreading over the front a thin enamel, which, in some instances, is hardly perceptible; outside generally cancellated, but entirely destitute of varices or umbilicus, and covered with an excessively thin epidermis.

Pyrula nexilis. Plate IV. fig. 29. Found in the London Clay at Barton Cliff.

The shells of this genus are few, and chiefly inhabit the Indian Ocean, as well as the coasts of South America.

In a fossil state, the Pyrulæ are met with in the newer formations; namely, the London Clay, Blue Marls of France, and the Super-Cretaceous rocks of Bordeaux and Dax, and *Calcaire-grossièr.*

Genus.—FUSUS.—*Lamarck.*

Generic Character.—Shell fusiform or subfusiform; spire usually turreted with many rounded volutions, and gradually acuminated, generally terminating in a pointed apex, although it is sometimes mammillary; for the most part, with longitudinal ribs and spiral grooves; aperture elliptical, ending in a lengthened straight canal; furnished with a horny operculum, having its nucleus at its acuminated lower extremity; outside covered by a rough epidermis.

Fusus longævus. Plate I. fig. 7. Found in the London Clay at Barton Cliff, &c.

This genus may be properly arranged in the following sections:—

Section 1.—Spire and canal of equal length, aperture elliptical, body ventricose, base of the aperture suddenly contracted into a straitened canal, as in *Fusus colus.*

Section 2.—Fusiform. Columella, with two or three transverse folds, immediately above the commencement of the canal, as in *Fusus infundibulum* (the Turbinella infundibulum of Lamarck).

The shells of this genus are numerous, and inhabit the seas of almost all countries.

Fossil Fusi are numerous, and occur in the London Clay, the *Calcaire-grossièr*, and the English Crag; Blue Marls of France, the Super-Cretaceous rocks of Bordeaux and Dax; also, in the Cretaceous group of rocks.

Genus.—TROPHON.—*De Montfort.*

Shell fusiform, spire produced; volutions numerous, generally rough, and provided with lamellar varices, and frequently spirally sulcated; aperture terminating in a moderately elongated canal; pillar lip smooth, and destitute of teeth or plaits; operculum corneous, unguicular, with a terminal nucleus.

Trophon antiquum. Plate I. fig. 12.

The species of this genus are mostly confined to northern seas, inhabiting rather deepish water. They are distinguished from those of the genus Fusus by their canals being shorter, and not so straight.

Fossil species are, for the most part, found in the Crag.

It will be observed that the variety of *Trophon antiquum*, which we have figured, is the sinistral, or that with its volutions turning to the left, or contrary to the ordinary manner. This is its most common form in the Crag, while the dextral, or right-handed variety is less frequently met with, but is the variety most common in the present seas, while the sinistral one is very rare. Mr. S. Wood thinks this last variety its normal condition, but Professor E. Forbes, on the contrary, looks upon the dextral variety as the normal form. Reversed shells are very rare amongst the mollusca.

Genus.—FASCIOLARIA.—*Lamarck.*

Generic Character.—Shell elongated, fusiform; the spire generally of equal length with the canal; aperture oblong-ovate, generally acuminate both above and below, ending in a nearly straight canal, provided with three oblique plaits at the

base of the columella, the lower one generally largest; operculum horny, thick, oval, and acuminated below.

Fasciolaria turbinelloides. Plate IV. fig. 32.

In their general form, the shells of this genus much resemble those of *Fusus*, but their want of the oblique folds, so conspicuously marked in *Fasciolaria*, at once render the difference obvious. They are distinguished from Turbinella by the great obliquity of the plicæ, and in the lower one being always largest.

The species are not numerous, and are principally inhabitants of the East and West Indian Seas.

The Fossil species are few, and occur chiefly in the new formations; namely, the Super-Cretaceous rocks of Bordeaux and Dax.

Genus.—Cancellaria.—*Lamarck.*

Generic Character.—Shell oval, thick, subturreted; spire short in most species, but produced in a few; body large, ventricose, greatly exceeding the spire in length; aperture subovate, not quite entire, the base being, for the most part, somewhat extended into a canal, distinct in most cases, but always short and recurved; outer lip transversely sulcated within; inner lip reflected over the columella, and part of the front of the body; columella plaited, varying in number and size; for the most part they are large, compressed, and much developed; in some instances they are small, few, and placed far within the columella, so as to be nearly obscured; at other times low down.

Cancellaria evulsa. Plate IV. fig. 33. Found in the London Clay at Barton Cliff.

Sowerby proposes that this genus should be separated into the following sections:—

1. The canal short, recurved, and produced; the superior fold on the columella compressed.
2. The canal short, recurved, and produced; the columella with two plaits, the lower one largest; the varices few, and irregular.
3. Aperture terminating in a produced canal; columella three-plaited, with distinct cleft varices.
4. Aperture terminating in a produced canal; columella two-plaited, and inflected towards the outer lip.

The genus consists of but few species, which are natives of the coasts of America, Africa, and the Indian Seas.

Fossil species are not uncommon, and occur in the London Clay at Hordwell, and in the same formation at Piacenza; the *Calcaire-grossièr* of Bordeaux, Cotentin, and Paris.

Bruguière placed several species of this genus among his Mitræ, as also some of the Marginellæ, Ancillæ, and Columbellæ. Some of the Cancellariæ approach near to several species of the genus *Turbinella*, but the transverse grooves on the outer lip is a strong distinguishing feature in the Cancellaria.

Genus.—Trichotropis.—*Broderip and G. B. Sowerby.*

Generic Character.—Shell turbinated or subfusiform, with spiral ridges or carinæ upon the volutions, and generally thin; spire more or less elevated, terminating in an acute apex; aperture subovate, acuminated at the base, so as to form a rudimentary canal, subconcentric, with a lateral nucleus; columella obliquely truncated and flattened, with an open umbilicus; operculum corneous.

Trichotropis borealis. Plate IV. fig. 24. Found in the Coral Crag at Sutton, and in the Mammiferous Crag at Bridlington; likewise in the Pliocene deposits on the banks of the Clyde.

The shells differ from Cancellaria in the form of the aperture, which resembles that of Purpura, and in the flattened columella, and likewise in the absence of folds.

The shells of this genus are marine, and inhabit Boreal seas. This species is known in a recent state, and is met with in the Hebrides, the estuary of the Clyde, and Zetland islands.

Genus.—Pleurotoma.—*Lamarck.*

Generic Character.—Shell fusiform, thick, turreted; spire generally longer than the body; aperture oval, with a canal more or less elongated at the base; outer lip thin, with a notch or fissure at the upper part, contiguous to the suture; columella smooth and nearly straight; operculum horny, acuminated; its nucleus situate at the lower extremity. Some of the species are covered with a thin epidermis.

Pleurotoma priscus. Plate IV. fig. 35. Found in the London Clay at Hordwell.

The Pleurotomæ are Oceanic shells, inhabiting the seas of Southern Europe, and the warmer portions of the globe.

Fossil species are only met with in the Tertiary formations; namely, the London Clay, *Calcaire-grossièr*, with other contemporary strata of Bordeaux, and the Appenines.

Genus.—Clavatula.—*Lamarck.*

Generic Character.—Shell turriculate, fusiform, generally longitudinally ribbed, frequently striate transversely; sometimes both, at other times smooth; aperture with the outer lip more or less sinuous, and retiring at its junction with the volutions of the body, and extending into a more or less short canal below; sometimes denticulate within, and provided with a small sinus at the suture.

Clavatula nebula. Plate IV. fig. 36. Found in the Red Crag at Sutton. The species are all small.

Lamarck instituted this genus for a division of the Pleurotomæ, embracing those species with a small, shallow sinus, but afterwards united them to Pleurotoma. Mr. Searles Wood has followed the original intention of Lamarck, and grouped together those with the side slit, represented by a somewhat obscure sinus, which, instead of being in the outer lip, is situated at the upper extremity of the aperture, at or near the junction of the body volutions.

Many recent species inhabit the British, Arctic, and other seas, and fossil species are numerous, and are met with in the Crag.

Genus.—Cerithium.—*Bruquière.*

Generic Character.—Shell greatly lengthened or turreted, with numerous volutions, more or less tubercular, or spinous, or rough, in a very few instances smooth, or spirally grooved; aperture subquadrate or ovate, its upper part modified within by the abdominal region of the body, with the peritreme a little thickened, and sometimes broadly reflected, and a groove at its upper extremity; columella arcuated, with a sharp spiral plica at its base, and forming the upper margin of the canal, which is somewhat short, truncated, and generally reflected; provided with a small horny operculum.

Cerithium pyramidalis. Plate IV. fig. 37. Found in the London Clay at Barton Cliff and Hordwell.

The species are very numerous, and subject to great variety in form; they inhabit the seas of almost all countries. The following are the principal peculiarities which they exhibit:—

1. Outer lip considerably dilated and reflected, prolonged over the canal at the anterior extremity, and connected to the termination of the columella; producing in the not reflected canal a circular aperture, with a sharp margin; external surface ribbed and decussated. *Cerithium sulcatum.*
2. Canal very short, with a prominent callosity at the posterior region of the inner lip. *Cerithium tuberculatum.*
3. Spire very short; aperture almost circular, and extremely short; the canal not protruding; surface granose. *Cerithium breviculum.*
4. Apex decollated in the adult shell; outer lip greatly dilated and reflected; almost no canal, the aperture nearly quite orbicular; outer surface longitudinally ribbed. *Cerithium decollatum.*
5. Outer lip thickened, but not reflected; hardly any canal; with numerous varices. *Cerithium varicosum.*
6. Posterior part of inner lip with a callosity; canal almost straight, and somewhat elongated; one varix opposite to the aperture; outer surface rugose. *Cerithium mutatum.*
7. Outer lip hardly thickened; inner lip thickened and prolonged; canal elongated and reflected; columella often with a plait in its centre. *Cerithium columna.*

8. Canal wide, very short, both sides of equal length; outer lip dilated towards the anterior part, and externally provided with one row of tubercles. *Cerithium Pacificum.*

The Cerithia seem intermediate between the genera *Terebra* and *Planaxis.* They are, however, distinguished from the latter by having a canal, of which it is destitute; and from Terebra, by the form of the columella and reflected canal; and although somewhat related to *Pirena*, they will at once be recognised by the back part of their outer lip being entire.

Fossil species are very numerous, and occur in the Blue Marls, south of France, the Super-Cretaceous rocks of Bordeaux and Dax, the Cretaceous and Oolitic groups of rocks.

Genus.—Ceritella.—*Morris and Lycett.*

Generic Character.—Shell turreted, spire acute, subulate, volutions flattened, their margins usually sulcated; the last volution large; aperture lengthened and oblique, canal very short; columella smooth, rounded, and slightly reflected at the base; outer lip thin.

Ceritella acuta. Plate V. fig. 25. From the Great Oolite, near Minchinhampton.

This genus was instituted for the reception of several subulate smooth shells, rarely longitudinally sculptured, whose characters differ from Terebra on the one hand, and Cerithium on the other; they are destitute of the decided twist which we find in the former genus; and the increased dimensions of the last volution, together with the elongated narrow aperture, separate them from the Cerithiæ; the base never terminates in a notch, but in a narrow, very short channel, which is turned slightly forwards and outwards; the volutions are generally flattened, and the length of the spire exceeding that of the aperture. No recent species have been discovered.

Genus.—Potamis.—*Brongniart.*

Generic Character.—Shell turreted; body short; spire long; aperture nearly semicircular, but destitute of a canal in the upper angle; base contracted into a short, slightly truncated beak; outer lip dilated; operculum corneous.

Potamis cinctus. Plate IV. fig. 38. Found in the upper marine formation at Headon Hill, and also in the same formation, Isle of Wight.

This genus of fresh-water shells is closely connected with *Cerithium*, differing, however, in the epidermis being corneous, generally decollated; the beak very short, and not recurved; in being destitute of a well-defined canal; but instead of it, a groove in the lip, in some species, and the aperture considerably shorter in proportion to its size than in Cerithium. Supposed to be a fresh-water genus of shells.

The genus consists entirely of fossil species, which seem to belong to the upper and lower fresh-water formations; the London and Plastic Clay, &c.

Genus.—Nerinæa.—*Defrance.*

Generic Character.—Shell turreted, oblong, subcanaliculated, with numerous volutions; body large, but somewhat contracted near the aperture; aperture small, oblique, subquadrate; columella provided with a strong fold, one on the inner lip, at the edge of the body volution, and one on the outer lip, which is thin.

Nerinæa Mosæ. Plate IV. fig. 41. Found in the *Calcaire-grossièr*, Paris Basin.

This genus is known only in a fossil state, and is peculiar to the Oolitic group of rocks. The prominent and large folds, on the superior angles of the aperture, distinguish it from all others.

BUILDING ARTS.

CHAPTER III.

In order to provide the reader with examples of a complete set of plans, we give, in Plate IV., the remainder of the drawings of the houses in Plates I. and II. Fig. 1 is a front elevation and section of the stables, the half to the right being the section. Fig. 2 is the ground plan of both stables, with scale attached. Fig. 3 is the "block plan" of both houses, and fig. 4 the elevation (half) of gate.

ILLUSTRATIONS DESCRIBED.

According to the plan of our proposed papers, we now proceed to describe the examples of the different styles of domestic architecture, as classified at the commencement of this article. Plates I. and II. are examples of the semi-detached style of house in the second class (suburban).

In Plates V. and VI. we give a set of plans of a row of "street houses," forming an example of the first class, into which we have divided domestic structures. In Plate V., fig. 1 is the front elevation, showing half only, and fig. 2 is the side elevation. In Plate VI., fig. 1 is the basement plan of the four houses; of the two end houses, *a* is the wash-house, eight feet by ten; *b* the larder, nine feet three by nine; *c* the potato-cellar, five feet six by five feet three; *d* the wine-cellar, five feet nine by five feet; *e* the coal-cellar; *f* the beer-cellar, ten feet by eight feet three. In the two centre houses, *g* the potato-cellar; *h* the beer-cellar, eight feet by seven; *m* the larder, ten feet three by eight feet three; *n* the wash-house, ten feet three by eight feet, and *o* the wine-cellar, five feet nine by four feet six.

In Plate VI., fig. 2 is the ground plan of the two end houses: *a a* are the drawing-rooms, nineteen feet six by fifteen feet six; *b b* the dining-rooms, nineteen feet six by fifteen; *c c* the kitchen, seventeen feet three by seventeen; *d d* the entrance-halls, seven feet wide; *e e* the sculleries, ten feet by nine feet nine; *f f* the pantries; *g g* closets. Of the two centre houses of the row, *h h* are the lobbies, seven feet wide; *i i* drawing-rooms, nineteen feet six by fifteen feet; *j j* dining-rooms, nineteen feet six by fifteen feet nine; *k k* kitchen, fifteen feet by fourteen feet three; *l l* sculleries, ten feet six by eight feet nine; *m m*, *o o* back stairs to yard.

In Plate VI., fig. 3 is the chamber plan. Of the two end houses, *a a* are the front bed-rooms, with dressing-rooms, *b b*, attached; *c e*, *c e* bed-rooms; *d d* clothes-closet; *f f* bath-rooms; *g g* water-closets; *h h* ante-rooms. Of the two centre houses, *i i* are the principal bed-rooms, with dressing-closets, *k k*, attached; *l l* front bed-rooms; *m m* clothes-closet; *n n* back bed-rooms; *o o* bath-rooms; *p p* water-closets. The following is the specification of this important example.

EXCAVATOR.

Excavate the ground to the depth of five feet below the level of the street. Fill in and well ram behind all walls when brought up level with the ground. Excavate for all areas to cellar windows. Cart away such parts of the excavations as may be directed. Lay a 12×9 earthenware drain longitudinally through the front cellars, and connect the same with the street sewer by a drain 16×12. The passages, wash-cellars, larders, and beer cellars, are each to have an eye brought up 9×9 with one brick length sides. Each eye to have a Lowe's patent stench grid. Connect the down spouts and the stench grids with the main drain by earthenware socket-pipes 6 in. diameter. Each grid and down-pipe to have a trap in the drain. Provide all necessary bends, junctions, eye-pieces, &c., required. Lay 4-inch socket-pipes from the slop-stones and bath-pipes. All the joints to be well puddled and laid solid. Make good at the walls with puddle wherever directed. Lay the whole of the cellar floor with a bed of cinders 9 in. thick, and level the same.

BRICKLAYER.

The whole of the walls to be built with good well-burnt and square common bricks, set in mortar composed of two parts sharp clean river sand, and one part new-fallen Woodthorpe lime. All the front and end walls to be 16 in. thick, with a cavity of two inches, and to be bonded alternately every three courses. The remainder of the outer walls to be $11\frac{1}{2}$ in. thick, with a cavity, and bonded as last described. All the party walls and cellar interior walls to be 9 in. thick. The back and cellar walls to be pointed for colouring. All the flues to be 14×9, and carried up separately to the height shown; to be pargetted, and to have a cavity chimney-pot,

each of the value of 6s. when set. Turn arches over all fire-places. Each fire-place to have an arch-bar $''3\times''\frac{1}{4}$, turned up at each end. Turn 9 in. common arches over all external openings. Set the slop-stones and boilers with seconds bricks with bull-nose corners. Cut all splays, bevils, chases, holes, &c., required for the several branches of the work, and make good after the same. Set all window-cills and door-steps, and steps to the cellars.

The proprietor will purchase the grates and boilers, and the contractor is to set the same in the most approved manner with fire-bricks. An average of 10 fire-bricks to be used for each grate. Turn arches over all drains at the several walls. All the walls to have two courses of footings, 6 in. deep each, and to project $2\frac{1}{4}$ in. each from the walls built thereon. The areas to be built with 9 inch walls. Build under the entrance hall where required. Build a shoot to each coal-cellar on flag-bottoms. All the cellar floor, except wash-house and passages, to be laid with seconds bricks on edge, and run with lime. Lay the area-bottoms with bricks flat below the window-cills. Build all the required projections for the mouldings, quoins, &c., and cut the same to the requisite forms shown by the detail drawings. Bed all bond timbers and plates. Set all gudgeon and sneck stones to cellar doors. Point all the back windows, doors, and copings. Build walls under the larder table and shelves. Build potato-bins, as shown.

MASON.

All the masonry to be done with the best stone, except otherwise specified. All the base course to be of an average thickness of 6 inches, polished and cramped at the joints. The top edge to be moulded as shown. The front Venetian window-jambs to be of stone up to the neck mould; the panels to be carved as shown. The window-cills to the front and ends to be 12×9, weathered. The keys of the door-arches to be of stone, moulded and carved as shown. The front-door steps to be 3 in. thick, polished, with 2 in. risers and square nosings. The plinths on each side of steps to be of stone. All the back windows to have cills tooled, weathered, and throated, 11×6. The chimney-caps to be of stone, 4 in. thick, with moulded edge and flue-holes perforated. The wash-houses and sculleries to have slop-stones the size shown on plan, 6 in. thick, and sunk 2 in.; to be tooled and holed for pipe; to have 3 in. tooled shelf at each end. The whole to be skirted with flag-polished skirting $12\times1\frac{1}{2}$, well cramped to walls. The back and cellar-steps to be 3 in. thick, self-faced, and tooled edges and end. The cellar-doors to have gudgeon and sneck stones, with the necessary holes cut and run with lead. The landing to the back-door to be 4 in. thick, tooled. All the area and other curbs to be 12×6, tooled and cramped at angles. The kitchen, scullery, pantry, and landing, to be laid with $2\frac{3}{4}$ in. best Barns flagging, with mortar on boards; the flags to be bedded on sand; to be 2-inch polished hearths to all the fire-places, 6 in. longer than the openings at each end, and 2 feet wide; all back hearths to be self-faced. The proprietor will purchase all the chimney-pieces, and the contractor is to fix the same with cramps to the wall. The coal grid to have a flag 3 ft. 6 in. by 3 ft. 6 in., 4 in. thick, and to have hole cut; provide and fix to the same a coal grid 18 in. diameter, with chain, bar, and staple complete. Flag the cellar, wash-houses, and passages with $2\frac{1}{2}$ in. self-faced Yorkshire flagging. The boilers to have 3 in. tooled tops, with holes cut for boiler. The wine-cellar to have 3 tiers of shelves, 3 in. thick, tooled, edged, let into walls, and flag divisions 3 feet apart. The larder to have a centre stone table, 4 ft. by 3 ft., tooled, and to have a shelf as shown, 3 in. thick, with tooled top and edge, 18 inches wide. The Lowe's grids to have a stone flag, 2 ft. by 2 ft., with hole and rebate cut. Cut all the requisite holes for iron and wood-work wherever required; run the holes for iron-work with lead. The back gables to have 14×3 tooled edges, coping-joints cut hollow, cramped, and run with cement. All the cellar window-cills to be 16×3, with tooled edges.

CARPENTER AND JOINER.

All the bearing timbers to be of Quebec pine; all the joiner's work, except otherwise specified, to be of St. John's pine—the whole to be sound, well seasoned, and free from knots, shakes, and any other defects whatsoever. Provide all centering and turning-pieces required for the bricklayer. All the windows, doors, and other openings which have to be cased, to have 6 wood bricks, $9\times4\frac{1}{2}\times3$ in. All doors and windows to have lintels 3 in. thick, and the full width of walls, except outside walls. All the floors, except otherwise specified, to have joists $8\times2\frac{1}{2}$, 12 in. apart, trimmers 8×3. One tier of bridging through at each floor $7\times1\frac{1}{2}$, and the dining and drawing-rooms to have two rows of bridging. All joists to be caulked to wall plates $4\frac{1}{2}\times1\frac{1}{2}$, and lay $4\frac{1}{2}$ in. on each wall. The lobbies to have joists $4\times2\frac{1}{2}$. The kitchen joists to be $9\times2\frac{1}{2}$; the sculleries and rooms over, and cistern to have joists $6\times2\frac{1}{2}$. The cisterns to have 3 tiers of bond timber, $4\frac{1}{2}\times3$, and to be lined with $\frac{3}{4}$ in. grooved and tongued boarding. Lay the bottom of cistern, also the flagged rooms on the ground floor, with inch rough boarding. Lay all the rest of the floors with 7×1 inch spruce pine boarding, straight, joint-nailed, punched, puttied, and dressed off, after the plastering is completed. The roof to have wall-plates 6×3, with wood nogs 2 ft. apart, $9\times4\frac{1}{2}\times3$, for securing cornice; to have pans $12\times3\frac{1}{2}$, not more than 6 ft. apart, fixed vertically. Spars $3\times2\frac{1}{2}$, $12\frac{1}{2}$ in. apart. Ridge-piece 7×2, tilting-piece $3\times1\frac{1}{2}$, ceiling joists $4\frac{1}{2}\times2$, well hung to pans. Hip rafters 8×2, valley rafters 12×3, valley boarding $9+1$. Skylight hoppers to be studded with 3×2 studs. The staircase to have a skylight 6 ft. by 4 ft., in two squares; sides and head 6×3, bottom 5×3, bars $5\times2\frac{1}{2}$, to have $\frac{3}{4}$ bead to the hopper angles. Fix a beaded lining 9×1 under the skylight, and plant a mould round the same 6×4. The front and ends to have moulded block cornices, and cornices under windows and pediments of wood to the form shown on the detail section. Cover the tops of pediments with inch rough boarding 15 in. wide. Lay all the cornice bottoms with inch gutter-boards and bearers to a proper fall, with drips 3 in. deep, 12 ft. apart. The back to have 12×1 moulded fascia boards, with inch gutters and bearers 9×1. The hips and ridge over porch to have $2\frac{1}{2}$ rolls and irons. The chimneys to have apron-board 8×1, and the back of chimneys to have gutter-boards 9×1. Prepare and fix in the roof a man-hole and trap-door complete. All the partitions to be framed and trussed; studs $4\frac{1}{2}+2$, posts $4\frac{1}{2}\times3$. Heads, cills, and braces, $4\frac{1}{2}\times3$; cross-pieces $4\frac{1}{2}\times1$. Form beams in the lobby, with brackets 12 in. deep. Trim and box all hearths. The front and ends to have windows, as shown in the drawing; $2\frac{1}{4}$ moulded sashes of deal, and frames, pulley-stiles, $1\frac{1}{4}$ in. thick; cills double repeated, of red deal, 3 in. thick; $\frac{5}{8}$ outside lining, $\frac{3}{4}$ inside lining, $\frac{5}{8}$ beads, $\frac{1}{2}$ in. parting beads. All to be made for plate glass; meeting rails to be hollow, moulded of oak $1\frac{1}{2}$ in. deep. All to be double hung with 2 in. axle pulleys, best cords and weights complete; $\frac{1}{2}$ parting laths between the weights; back linings $\frac{1}{2}$ in. thick. All the back sashes to be 2 in. thick, made for common glass; the frames, &c., to be as before described, and all to be double hung. The kitchen to have $2\frac{1}{4}$ moulded sashes and Venetian frame, with hollow mullions for weights. The plate-glass windows to have brass sash-fasteners of the net value of 2s. 6d. each, and the remainder of the sash-fasteners to be of the value of 1s. 6d. each. All the windows to have inch linings, flush with the plastering. All the cellars to have 2 inch York lights; frames $4\frac{1}{2}\times3$, head $4\frac{1}{2}+3$, and Baltic cill $4\frac{1}{2}\times3$. One half of each window to slide, and to have a screw fastener. The dining-room and drawing-room windows to have $1\frac{1}{2}$ framed and moulded shutters, with bead, butt, back, and bead, butt, and moulded back flaps, 2 panels in height; moulded elbows, backs, soffit, and roller rails, $1\frac{1}{4}$ in. thick, to match. Shutters $\frac{3}{8}$ beaded capping inch back linings, $1\frac{1}{2}$ in. ground and framed, 7 in. double-faced architrave; $\frac{1}{2}$ in. square skirting, moulded blocks to architrave 9 in. deep; the shutters to be hung 2-3 in. butts and back laps, with $2\frac{1}{2}$ back lap hinges, to have a spring shutter bar and shutter latch with best china knob; one shutter to each window to have a 6 in. brass flush bolt at the bottom; the backs of the stone mullions to have a $1\frac{1}{4}$ in. moulded pilaster and carton pierre truss, the depth of the roller rail, of the value of 15s. each. Each bottom sash to have two brass lifting handles. All the rest of the ground-

floor windows to have $1\frac{1}{2}$ in. framed shutters and back flaps to fold back against the walls, hung to $1\frac{1}{2}$ in. hanging stile, with 2-3 in. butts each, and $2\frac{1}{2}$ in back flap hinges. The frame to project 4 in., $1\frac{1}{2}$ in. thick, rebated to receive shutter-back lining, $4\times\frac{1}{2}$; window bottom $5\times1\frac{1}{2}$ and rounded. Single moulds round to have strong shutter-bar 2 ft. long, to have 2 brass knobs. The shutters to have roller-rail 4 in. deep, and $\frac{5}{8}$th capping. The lobby shutters to be as last described, with single-faced architrave 5 in. wide; 2 in. moulded window-bottom, with mould under projecting 4 in., and two terra cotta trusses of the net value of 5s. each. All the bed-room windows, except otherwise specified, to have arch linings $1\frac{1}{4}$, rounded; window bottoms and single moulds round. The windows over drawing and dining-rooms to have 6 in. single architraves round, $1\frac{1}{4}$ moulded window backs $6\times\frac{1}{4}$, skirting square blocks to architraves 6 in. deep, $\frac{5}{8}$ths beaded capping. All the borrowed lights to be 2 in. thick, moulded, and made for common glass, to have inch casings, $1\frac{1}{4}$ rounded window bottoms, and single moulds round both sides. All the cellars to have inch batten doors, grooved and tongued, hung with bands and gudgeons 18 in. long; to have thumb latch and 8 in. stock lock, except to potato and coal cellars. All the cellar doors to have iron grids 6 in. deep, and the full width of the doors, and to be fixed over the doors. The front entrance doors to be $2\frac{1}{4}$ thick, large collection moulds, double-margined, hung to rebated and double-beaded and moulded frame, as shown, with 3-4 in. butt hinges; to have moulded transom and circular fan-light in one square; to have single moulds round, and blocks. To have a 10-in. draw-back lock, night-bolt, and chain, 2-8 in. $\frac{3}{4}$ barrel bolts, and large ornamental bronze knob. The back doors to be 2 in. thick, bead, flush, and square, hung to $4\frac{1}{2}\times4$; rebated and beaded door-frames, with 2-$3\frac{1}{2}$ in. butts, to have transome and fanlight over single moulds round 10-in. carpenter's lock and black furniture, two 7-in. $\frac{3}{4}$ in. barrel bolts. The drawing and dining-rooms to have framed and double-moulded and margined doors hung to $1\frac{3}{4}$ in. rebated casings, with two $3\frac{1}{2}$ butts each; to have 7-in. double-faced architraves round both sides, and cored blocks to match windows to have $7\times\frac{5}{8}$ mortice-locks and night-bolts, with black furniture on one side and china furniture on inside, of approved pattern. The kitchens and bed-rooms on first floor over dining and drawing-rooms to have 2 in. double-moulded doors; all the rest of the rooms on first floor to be $1\frac{1}{2}$ in. thick, double-moulded, and the remainder of the doors throughout to be $1\frac{1}{2}$, single-moulded, and framed; the whole to be hung to $1\frac{1}{2}$ in. rebated casings, to have 7-in. carpenter's locks, night-bolt, and black furniture, and single moulds round both sides, except the lobby side. The doors to rooms over dining and drawing-rooms, to have 5-in. single-faced architraves and blocks, as well as the rest of the doors last specified on the landing side. Plant $\frac{3}{4}$ beads to all external angles; the dining and drawing-rooms to have a double-moulded base, 14 in. deep. The lobby, staircase, and rooms over kitchen, dining and drawing-rooms to have a 9-inch moulded skirting. All the remainder of the rooms, &c., to have a 7×1 torus skirting; the whole to have nogs 2 ft. apart—no wedges to be driven within 5 in. of any flue. The baths to be framed with $1\frac{1}{2}$ in. moulded front, to have polished mahogany capping, $6\times1\frac{1}{2}$. Prepare and fix $1\frac{1}{4}$ in. pitch pine treads, inch risers, moulded nosings let into $1\frac{1}{2}$ in. moulded notch-board, mitred strong board and nosings, $3\frac{1}{2}\times2\frac{1}{2}$. Mahogany moulded and polished hand-rail, electro-bronzed cast-iron open ornamented balusters, one to each step. Mahogany carved newel of the net value of 50s. to design to be given. Spring-trees to be $7\times3\frac{1}{2}$ double curtail steps, wreaths, and knees complete. Case the landings with inch-beaded and double-moulded fascia board 10 in. deep. Enclose the lower staircase with a $1\frac{1}{2}$ framed and moulded spandril, with a $1\frac{1}{2}$ door to match on top of cellar steps hung to 3×2 rebated casings, with two 3 in. butts; to have single moulds round one side, 7 in. carpenter's locks, and two brass neck-bolts. The cellar-steps to have a $3\times2\frac{1}{2}$ deal hand-rail, and 4×4 square and chamfered newels cramped to stone-work and framed to floor. Fix steps as before described to all doorways where required. The carved newels to have a $\frac{3}{4}$ in. bolt, with plate through the joists. The water-closets to have a framed partition moulded on both sides to divide off the ante-room, with door to match; to have a 6-in. latch and brass bolt to ante-room door. Lay a wood-wrought coping in the potato-bins, $4\frac{1}{2}\times3$. The top of kitchen window to have a cornice, and to be covered with inch boarding and 3×2 bearers. Case all the pipes with inch-beaded casing. Prepare and fix in the large cistern a double-boarded hot-water cistern, 3 ft. by 3 ft., and 3 ft. the depth of the cold-water cistern. Cover the same with inch boarding. The kitchen to have $1\frac{1}{2}$ framed cupboard folding front, 3 drawers deep, $1\frac{1}{4}$ drawer-fronts dovetailed, $\frac{3}{4}$ backs and sides, $\frac{1}{2}$ in. bottoms, runners, and rails complete. The cupboard to have 4 in. shelves in height, and pin rail $3\times\frac{3}{4}$ round, with $1\frac{1}{2}$ brass hooks 6 inches apart. The drawers to have an inner case. Doors to be hung with 2-3 in. butts, each to have hook and eye, and cupboard lock. The drawers to have two black knobs each, and one drawer lock each set. To have single moulds, round and square, skirtings complete. All the bed-rooms on the first floor to have a $1\frac{1}{2}$ in. moulded cupboard front, the whole height of room in two heights; to have two shelves inch thick, and pin rail, with hat and cloak hooks 6 inches apart; to have black knobs, cupboard latch, and hook and eye, and single moulds round, complete. The scullery to have two shelves round 12×1, and bearers. Pantry to have four shelves in height 12×1. China closet four tiers of shelves, 9×1. All the shelving in the scullery, kitchen, pantry, and closet, to be $3\times\frac{3}{4}$, hook, rail, and $1\frac{1}{2}$ brass hooks 6 inches apart. Provide and fix, in addition to the above-mentioned shelving, 30 feet of shelves to each house, 12×1. Provide and fix 20 feet to each house of moulded hat and cloak rail, 6×1, and 20 double brass cloak pins. Provide a lid to each boiler. Each larder to have a hang shelf, 4 feet long, 2 feet wide, $1\frac{1}{4}$ thick, with $\frac{1}{2}$ in. bar under, and $\frac{5}{8}$th hangers screwed to joists. Provide and fix twelve meat-hooks to each house. Provide and fix the whole of the wrought-iron rails and ornamental balconies, as shown by detail drawings, and as may be selected according to the same at the iron-founder's.

PLUMBER.

Lay the front gutters with 6 lbs. lead, 2 ft. 6 in. wide. Lay the back gutter with 6 lbs. lead, 18 in. wide. Cover the pediments, lower cornice, and kitchen window-flat with 5 lbs. lead, and flash the same with 4 lbs. lead, 6 in. wide. Aprons and chimney-gutters, 18 in. wide, of 5 lbs. lead, and step flashings 12 in. wide, of 4 lbs. lead. Valleys 5 lbs. lead, 18 in. wide. Skylights 5 lbs. lead, 14 in. wide, and apron and gutter-pieces of 5 lbs. lead, 18 in. wide. Hips and ridge over porch with 5 lbs. lead, 18 in. wide. Balcony bottoms, 5 lbs. lead, turning up against walls 4 in., and 4 lbs. flashing round, 4 in. wide. Line the cisterns with 5 lbs. lead, and lay the bottoms with 6 lbs. lead, all well soldered at the angles. Line the hot-water cistern, and cover the top with 5 lbs. lead. The cold-water cistern to have $2\frac{1}{2}$ in. plug and washer, trumpet-mouth top, 9 inches diameter. The hot-water cistern to have $1\frac{1}{4}$ supply pipe, 12 lbs. to the yard, and $\frac{3}{4}$ return pipe, 7 lbs. to the yard. The cistern to be supplied from the town's mains, with inch lead pipe, 10 lbs. to the yard, with brass stop-tap and ball-tap. Supply the slop-stones and water-closets with $\frac{3}{4}$ lead pipe, 7 lbs. to the yard, with $\frac{5}{8}$ths best bib taps. The slop-stones to have $1\frac{1}{2}$ in. waste pipes and bell trap. Provide and fix a best Kirkwood's patent water-closet complete to each house; to have a 5 inch soil-pipe, each of 6 lbs. lead, with proper S traps, top and bottom. Provide and fix a strong zinc bath to each house, of the net value of £5; each to have inch hot water supply pipe, 12 lbs. to the yard, and a $\frac{3}{4}$ in. return pipe; to have $1\frac{1}{2}$ in. waste pipe, plug and wash, and to have proper bath taps complete. The bath to be lined underneath with 5 lbs. lead, and turned up 6 in. on each side with waste pipe —the baths to be supplied from a hot-water boiler, set at the back of the kitchen-range, with all necessary copper and expansive pipes complete. All the slop-stones to be supplied with hot water by a $\frac{3}{4}$ in. lead pipe, 9 lbs. to the yard, and $\frac{5}{8}$ths Chrime's bib-tap. All the water to be taken from the roof to the drains with 3 in. lead pipes of 5 lbs. lead, with heads, socket-pipes, and shees complete. All the laps and unflashings to be not less than 3 in. Well dress over all drips and cess-

PLATE E.

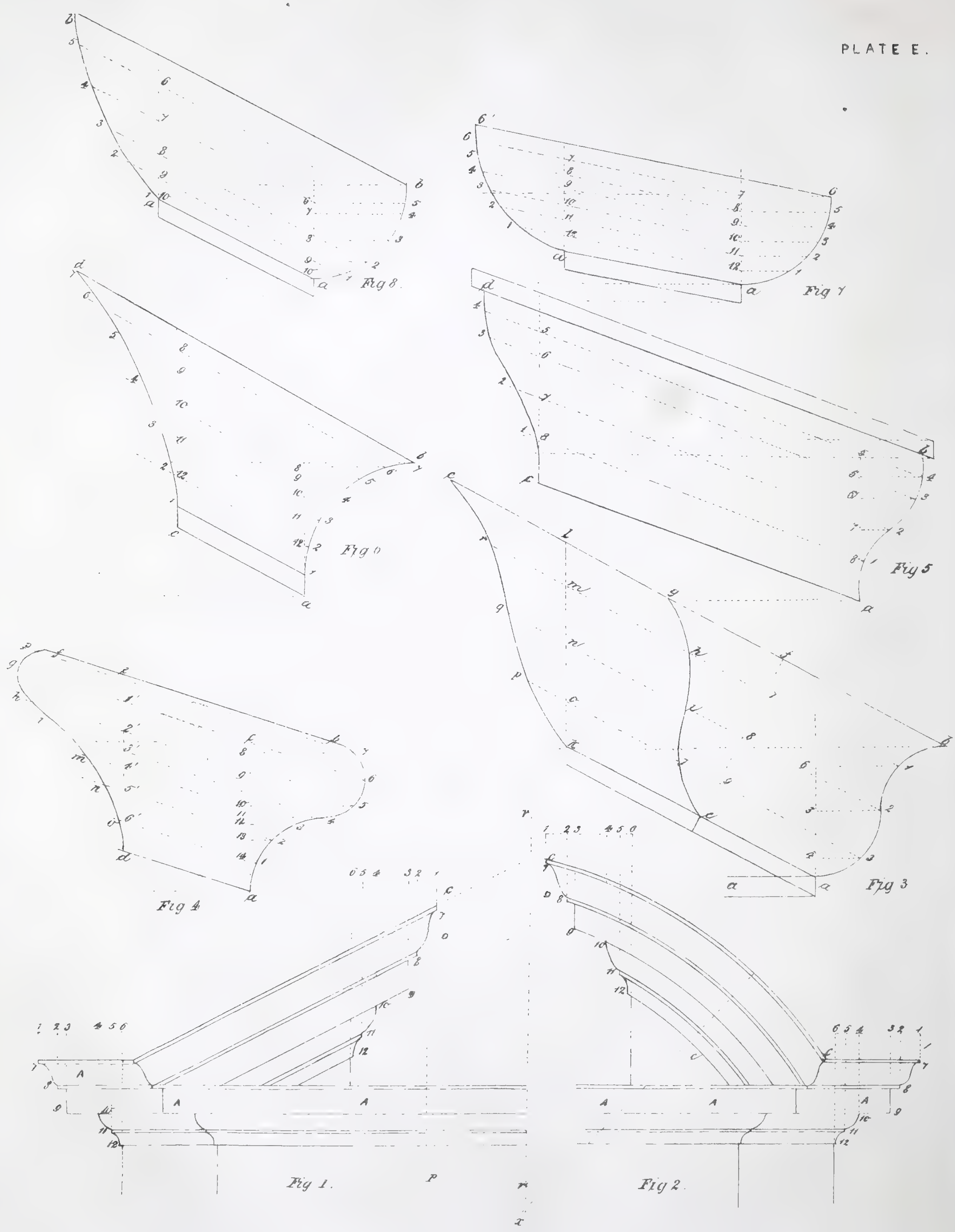


Fig 8. Fig 7. Fig 6. Fig 5. Fig 4. Fig 3. Fig 1. Fig 2.

pools. Fix a rose on the top of each cesspool. The plumber to make good all damage from leakages arising from defects in his work up to the time of the settlement of the accounts.

GLAZIER.

All the front windows and fanlights to be glazed with the best British polished plate-glass. The passage-window to be glazed with 26-ounce polished Chance's sheet-glass, ground, with bright ornament, to have a coloured border round, 6 in. wide, the pattern to be the convolvulus leaf and flower, as shall be directed by the architect. The centre square in the upper sash to have a coloured boquet of flowers, 9 in. diameter. The skylights to be glazed with rough plate-glass $\frac{3}{8}$ of an inch thick. All the remainder of the glazing required to be done with best Newcastle glass. The whole to be well bedded in oil putty, and dressed off. Make good all broken squares at the completion of the building, and leave the whole clean and perfect.

SLATER.

Cover the roofs with the best 2nd slates, on fir laths $2\frac{1}{2}\times\frac{3}{4}$, nailed with wrought-iron nails to the spars. Each slate to have two copper nails; the lap to be 3 inches, and seam not less than 6 inches. Double eaves throughout. Point the whole with good hair mortar; point all flashings. The hips and ridges to be covered with the best roll-ridge tiles, and pointed with black cement. Cut all bevils required, and make good all broken slates at the completion of the works.

PLASTERER.

The cellar ceilings to have one good coat of lath and plaster, and to be twice coloured. The dining-room, drawing-room, and passage ceilings, to have three coats of lath and plaster, finished in the best manner, and twice whitened. All the rest of the ceilings throughout to have two good coats of lath and plaster, and to be twice whitened. Lath and plaster, two good coats; all wood partitions. All the walls, except otherwise specified, to be plastered with two good coats. The kitchen, scullery, pantry, staircase, and back-passage walls, to be polished for painting. The cellars and back of the building to be twice coloured. The front and two ends of the buildings, and the chimney-stalks, are to be covered with the best Greave's Portland cement, mixed, as used, in the proportion of one-half pure cement, and one-half good washed, clean, sharp river sand. The whole of the cement to be used as soon as mixed. All the cement work to be neatly jointed, to represent stone. The whole of the mouldings, cornices, rustics, enrichments, and every other finishing whatsoever, are to be done, until the wood and lead work of the cornices are completed, or to be carried on in weather which the architect may consider unfavourable. A cast of all enrichments to be submitted for the architect's approval. Twice colour the cement to represent stone, as the work proceeds; when finished, colour the same a third time. Bed-set and point all window and door frames, and make good wherever required, after the other branches of workmen.

The dining and drawing-rooms to have cornices, according to detail drawings, 2 feet girth, with enrichments 15 inches girth. Passages to have cornices 18 inches girth, with enrichments 10 inches girth. The three principal bed-rooms, passage, and bath-room, to have plain cornices 15 inches girth. The passages to have beams panneled, and mouldings enriched, and to have terra cotta trusses, of the net value of 20s. each, as shall be chosen or designed hereafter by the architect. The dining and drawing-rooms to have carton-pierre ceiling flowers, of the net value of £2 each. The entrance porches to have ceiling flowers, of the net value of 20s. each. Cut and rim all beads and quirks required. Twice colour all cornices, and do every other matter and thing necessary to complete the plastering and cement work.

PAINTER.

The whole of the wood and iron work, inside and outside, usually painted, is to have four good coats of best oil paint, of approved tints, the first coat to be a good white-lead. The cornices outside to be finished dead, to represent stone. The outside doors, sashes, and frames, to be finished bronze green. The drawing-room to be finished white and gold; the dining-room maple and gold, and twice varnished. The enrichments, in all the cornices and ceiling flowers, to be picked out in gold. The staircases, lobbies, and kitchen, and two bed-rooms, to be finished oak or maple, and twice varnished. All the remainder of the bed-rooms to be finished with party colours. The bath-room walls to be painted five coats of oil paint and grained senna marble, and twice varnished. All the woodwork in the bath-room to be grained mahogany, and twice varnished. The varnishing, in all cases, to be done with two coats of best copal varnish. Paint, three coats, all the stone chimney-pieces and grates. All the papers will be purchased by the proprietor, and the contractor is to hang the same in the most careful manner. The paper on the lobby and staircase walls to be twice varnished. Make good the painting and papering at the conclusion of the work, wherever required, and leave the whole perfect and clean.

MECHANICAL DRAWING.

CHAPTER XIII.

We now proceed to the problems in connection with the describing of the various "curves" used in laying out the form of teeth of wheels, &c., as the "cycloid," "epicycloid," "involute," "conchoid," and "cissoid."

To describe the curve known as the cycloid, in fig. 107.

The cycloid is a curve generated by a point in the circumference of a wheel or circle, rolling along a plane surface, the distance rolled along being equal to the circumference of the circle, during one revolution of the circle. The head of a nail on the outside of a cart-wheel traces this curve, if the wheel moves along a line equal to the circumference of the wheel, in the time occupied by one complete revolution.

The diagram in fig. 107 shows one method of describing this curve approximately correct. Draw any line, 2, 1. Describe from centre, *a*, with radius, *a b*, a circle touching this line in the point, 9. Divide the diameter, *a* 9, into seven equal parts; make *c d* equal to eleven of these parts. Divide *c* 9 into any number of equal parts, as 9; and from these points draw perpendicular lines, meeting a line, *a d*, drawn through the centre, *a*, parallel to *c* 9. From the points thus obtained on the line, *c d a*, as *e*, *f*, *g*, *h*, &c., describe circles of same radii, as *a b* 9. Divide the semicircle, *j*, *s*, into nine equal parts (same number as *c* 9 is divided into), and letter them, say—*m*, *n*, *o*, *p*, &c., With radius, *j m*, from the point, 1, on the line, *c* 8, cut the circle described from *d* in the point, *a'*. With *j n* as radius, from the point, 2, on line, *c* 9, cut the circle described from *e*, in the point, *b'*. With the radius, *j o*, from the point, 3, on *c* 9, cut the circle described from the point, *f*, in the point, *c'*. With radius, *j p*, from the point, 4, cut the circle described from *g*, in the point, *d'*; and so on, until the last radius used is *j o*, and the circle described from the centre, *l*, is cut in the point, *v*. Through the points thus obtained draw the curve by hand, as at the left-hand side of the diagram.

Another method of describing the curve is given in fig. 108. Let *a*, *b*, *c*, be the circle rolling on the line *a d* (half the length of line when the curve is fully described). Draw the diameter, *a b*; divide the circumference, *a b*, into any number of equal parts, as twelve in the diagram. Lay off twelve of these parts, from *a* to *d*, and, from the points thus obtained, draw lines perpendicular to *a d*, cutting a line, *c* 11, drawn through the centre, *c*, parallel to *a d*. From the points 1, 2, 3, and on the line, *c* 11, describe arcs or semicircles, with radii equal to *c a*. With radius, *a* 1, from the point 1, on the line *a d*, cut the circle described from the point 1, on the line, *c* 11, in the point, *m*. With the radius, *a m*, from point 2, on *a d*, cut the circle described from the point 2, on line *c* 11, in *n'*. With radius, *a n*, from point 3, on line *a d*, cut the circle described from point 3, on *c f*, in *o'*. Proceed thus until the last radius, *a s*, described, from the point 11 in *a d*, cuts the circle described from the point 11 in *c f*, in the point, *t*. Through the points thus obtained, draw the curve by hand. The curve may be finished by extending the line, *a d*, and carrying out the same operations on the other side of *e d*.

EXPERIMENTS ON THE QUALITIES OF DIFFERENT KINDS OF COAL,

Made under the authority of the Navy Department of the United States.

By Professor Johnson of Philadelphia.

[In virtue of an Act of the American Congress, authorising the making of experiments on the properties and relative values of different kinds of coal, Professor Johnson completed an extensive series of experiments, the results of which were printed for the use of the Senate.

We insert from that work the following series of Six Tables exhibiting the relative value of coals according to their characters, with the remarks annexed to it.]

The tables here presented, containing, first, a general synoptical view of the character and efficiency of the several coals, and secondly, a number of distinct classifications in reference to different characters considered to be of the most practical importance, and based, in every instance, on the numerical results of experiment, will, I trust, be found highly serviceable in guiding those whose duty it may be to make choice of fuel for the naval or other public service, to the selection of such as will answer the specific object for which they may be procured.

Names of coals, arranged in the order of their Relative Weights.	Pounds to a cubic foot by experiment.	Relative weights.
Beaver Meadow, slope No. 5,	56·19	1·000
Atkinson and Templeman's,	52·92	·942
Scotch, ...	51·06	·909
Newcastle, ...	50·82	·904
Pictou (Cunard's), ...	49·25	·876
Liverpool, ...	47·88	·852
Cannelton (Indiana), ...	47·65	·848
Dry pine wood, ...	21·00	·374

Names, in the order of Rapidity of Ignition.	Time required to bring the boiler to steady action, in hours.	Relative rapidities of ignition.
Cannelton (Indiana), ...	0·50	1·000
Newcastle, ...	0·84	·595
Pictou (Cunard's), ...	0·85	·588
Liverpool, ...	0·86	·581
Scotch, ...	0 96	·521
Atkinson and Templeman's,	0·99	·505
Beaver Meadow, slope No. 5,	2·42	·207

Names, in the order of Completeness of Combustion.	Pounds of unburnt coke on the grate after each trial.	Relative completeness of combustion.
Pictou (Cunard's), ...	3·7	1·000
Atkinson and Templeman's,	5·1	·725
Scotch, ...	5·7	·649
Cannelton (Indiana), ...	6·4	·578
Newcastle, ...	10·7	·346
Liverpool, ...	11·1	·333
Beaver Meadow, slope No. 5,	61·2	·060

Names, in the order of Evaporative Power for Equal Weights.	Pounds of steam produced from water at 212°, by 1 lb. of fuel.	Relative evaporative power for equal weights.
Atkinson and Templeman's,	10·70	1·000
Beaver Meadow, slope No. 5,	9·88	·923
Newcastle, ...	8·66	·809
Pictou (Cunard's), ...	8·48	·792
Liverpool, ...	7·84	·733
Cannelton (Indiana), ...	7·34	·686
Scotch, ...	6·95	·649
Dry pine wood, ...	4·69	·436

Names of coals, in the order of Evaporative Power under Equal Bulks.	Pounds of steam from 212° produced by 1 cubic foot of each coal.	Relative evaporative power for equal bulks of coal.
Atkinson and Templeman's,	566·2	1·000
Beaver Meadow, slope No. 5,	556·1	·982
Newcastle, ...	439·6	·776
Pictou (Cunard's), ...	417·9	·738
Liverpool, ...	375·4	·663
Scotch, ...	353·8	·625
Cannelton (Indiana), ...	348·8	·616
Dry pine wood, ...	98·6	·175

Names, in the order of freedom from Waste in Burning.	Per-centage of total waste, in clinker and ashes.	Relative freedom from waste.
Dry pine wood, ...	0·307	16·417
Liverpool, ...	5·04	1·000
Cannelton (Indiana), ...	5·12	·984
Newcastle, ...	5·68	·887
Beaver Meadow, slope No. 5,	6·74	·748
Atkinson and Templeman's,	7·96	·633
Scotch, ...	10·10	·499
Pictou (Cunard's), ...	12·06	·418

If an equal importance could be attached to every one of the qualities of coals which form the bases of the six ranks above given, then the *sum* of the ratios or relative values found in the last columns would, for any sample, give nearly its true relative value in the market. Such equality does not, however, exist. Nor is it easy to assign the exact relative weight or importance of the several qualities indicated. For different purposes they must be differently estimated. Thus, when sold by weight and used on shore, the weight per cubic foot, as given in the first rank, is a point of little moment. Space for stowage is easily obtained. But in steam navigation, bulk, as well as weight, demands attention; and a difference of *twenty per cent.*, which experiment shows to exist between the highest and the lowest average weight of a cubic foot of different coals, assumes a value of no little magnitude.

For the purposes of steam navigation, therefore, the rank most important to be considered is that in which the names of coals stand in the order of their *evaporative* power, under given bulks. This is obviously true, since, if other things be equal, the length of a voyage must depend on the amount of evaporative power afforded by the fuel which can be stowed in the bunkers of a steamer, always of limited capacity.

As every sample of coal has been allowed a fair opportunity to exhibit its own distinctive character, it would be useless to attempt to substitute for the results of practical experiments, on such a scale as is here presented, any mere *opinions* or conjectures derived from observations made at random, with no standards of time, weight, or magnitude; or even any *theoretical conclusions* drawn from tests, however skilfully applied, merely to single hand specimens. It has been my aim in all these researches to avoid matters extraneous to the experiments themselves and to their legitimate interpretation. It has not been deemed expedient to swell this report by the introduction of matters not within my own cognizance.

It will not fail to be remarked, that the justly celebrated foreign bituminous coals of Newcastle, Liverpool, Scotland, Pictou, and Sidney, coals which constitute the present reliance of the great lines of Atlantic steamers, are fully equalled or rather surpassed in strength by the analogous coals of eastern Virginia; that they are decidedly surpassed by all the free-burning coals of Maryland and Pennsylvania; and that an equally decided advantage in steam-generating power is enjoyed by the anthracites over the foreign coals tried, whether we consider them under equal weights or equal bulks.

Experiment appears to demonstrate that, for the purpose of *rapid* evaporation, and for the production of illuminating gas, the coal of In-

diana, though neither very heavy nor very durable, is inferior to none of the highly bituminous class to which it belongs; since in heating power, and in freedom from impurity, it surpasses the splint and cannel coal of Scotland.

ON THE CLEANING OF THE WIRE CYLINDER OF THE SAFETY LAMP.

By Theodore F. Moss, Mining Engineer.

(From the Franklin Journal.)

The ordinary method of cleaning the wire cylinder of the safety lamp, by heating it over the flame of burning shavings, is capable of much improvement, as by this process it is found to become brittle, and consequently to impair the safety of using it. The coal dust, which contains more or less sulphur, combines with the oil and forms a tough mass, which hitherto has been taken off by the above way, but the wire becomes red-hot and readily combines with the sulphur of the coal dust, and consequently becomes brittle and unsafe. In mines where there is much sulphur this is found a great inconvenience, and the cylinders must be renewed from time to time, if it is wished that they should retain the quality which their name implies.

In the Bulletin du Musee d'Industrie, it is proposed to clean the wire cylinders by washing them in a boiling solution of soda, which it effects fully, soap being formed by the combination of the oil and alkali. In Karsten's Archives of Mineralogy aud Mines, the cleaning with soda is very strongly recommended, and the experience of several miners given, among which we may relate the following :—

At the Gonley mines, in the district of Worms, the carbonate of soda of commerce is used, which contains 80 per cent. of soda, this, to be rendered caustic, requires an addition of unslacked lime. The soda is dissolved in water, in the proportion of one to ten, and one part of unslacked lime is added to four parts of soda; the whole is then raised to a boiling heat, the wire cylinder to be cleaned is left in the boiling solution about 6 minutes; in this short time the oil has fully combined with the soda, and the soap formed combined with the dirt, after which follows the brushing, rinsing, and drying. At the Gonley mine, 40 or 50 of these cylinders are placed at once in the solution, and at the same mines, daily, from 80 to 90 cylinders washed at the cost per week of 10 to 15 cents. The same liquid can be used for a length of time by the proper addition of water, soda and lime, especially if the undissolved precipitate is removed, or, better, if a filtered solution is used.

In the mining circle of Laurbruck, soda of commerce contains from 90 to 95 per cent. of soda. The solution is made of one part soda to eight of water, otherwise one proceeds as at the Gonley mine.

It is to be hoped that from the simplicity and cheapness of the process, it may be introduced at those mines in this country which may be under the disagreeable necessity of using the safety lamp.

ON A NEW SYSTEM OF GUAGES.

By Mr. Holtzapffel.

ON THE GUAGES AT PRESENT USED FOR MEASURING THE THICKNESSES OF SHEET METALS AND WIRES, AND PROPOSALS FOR A NEW SYSTEM OF GUAGES, FOUNDED ON THE DECIMAL SUBDIVISION OF THE STANDARD INCH.

In setting out the Tables of the dimensions of saws, the author could only express their several thicknesses, in the measure always employed for that purpose, namely, in the sizes or numbers of the "Birmingham wire guage," and to render these measures intelligible to the general reader, the author then determined to introduce in this appendix—first, the exact values of the principal guages in use for sheet metals and wires, a subject he believes to have been hitherto overlooked; and secondly, a proposal he has long desired to see carried out, namely, an easy and exact system of guages for sheet metals, wires, and general purposes, founded on the decimal division of the inch; and in which system, the nomenclature should be so completely associated with the actual measures, as to convey to the mind, even in the absence of the guages themselves, a very close idea of the several spaces of the guage, or of the thicknesses or sizes of the works measured thereby.

It is to be observed at the outset, that the guages for measuring wires and sheet metals, are usually thick plates of steel of several sizes and forms, around and near the edges of which are first drilled various holes; the next step is to saw a notch from the edge into every hole, saws of the widths of the several notches being used; and lastly, little parallel plates of steel, called *drifts*, which are hardened and tempered, are driven into the notches, in order to smooth the sides of the same and render them of uniform width, after the manner of various other applications of drifts.

It should be further observed that the Birmingham and other guages seem to have been originated in a great measure accidentally, or almost by the eye alone, and without any attempt at system, either as regards the values of the intervals between the successive measures or numbers, or their correspondence with the subdivisions of the inch. And as moreover guages, nominally the same, have been made by various manufacturers with insufficient aim at unity of measures, some irregularity thence exists amongst the guages in common use, notwithstanding that they may be nominally alike.

Values of Guages for Wire and Sheet Metals in General Use. Expressed in Decimal Parts of the Inch.

SECTION ONE.		SECTION TWO		SECTION THREE.					
Birmingham Guage for Iron Wire, and for Sheet Iron & Steel.		Birmingham Guage for Sheet Metals, Brass, Gold, Silver, &c.		Lancashire Guage for round Steel Wire, and also for Pinion Wire. The smaller sizes distinguished by Numbers. The larger by Letters, and called the Letter Guage.					
MARK.	SIZE.	MARK.	SIZE.	MARK.	SIZE.	MARK.	SIZE.	MARK.	SIZE
0000—	·454	1—	·004	80—	·013	40—	·096	A —	·234
000—	·425	2—	·005	79—	·014	39—	·098	B —	·238
00—	·380	3—	·008	78—	·015	38—	·100	C —	·242
0—	·340	4—	·010	77—	·016	37—	·102	D —	·246
1—	·300	5—	·012	76—	·018	36—	·105	E —	·250
2—	·284	6—	·013	75—	·019	35—	·107	F —	·257
3—	·259	7—	·015	74—	·022	34—	·109	G —	·261
4—	·238	8—	·016	73—	·023	33—	·111	H —	·266
5—	·220	9—	·019	72—	·024	32—	·115	I —	·272
6—	·203	10—	·024	71—	·026	31—	·118	J —	·277
7—	·180	11—	·029	70—	·027	30—	·125	K —	·281
8—	·165	12—	·034	69—	·029	29—	·134	L —	·290
9—	·148	13—	·036	68—	·030	29—	.138	M —	·295
10—	·134	14—	·041	67—	·031	27—	·141	N —	·302
11—	·120	15—	·047	66—	·032	26—	·143	O —	·316
12—	·109	16—	·051	65—	·033	25—	•146	P —	·323
13—	·095	17—	·057	64—	·034	24—	·148	Q —	·332
14—	·083	18—	·061	63—	·035	23—	·150	R —	·339
15—	·072	19—	·064	62—	·036	22—	·152	S —	·348
16—	·065	20—	·067	61—	·038	21—	·157	T —	·358
17—	·058	21—	·072	60—	·039	20—	·160	U —	·368
18—	·049	22—	·074	59—	·040	19—	·164	V —	·377
19—	·042	23—	·077	58—	·041	18—	·167	W —	·386
20—	·035	24—	·082	57—	·042	17—	·169	X —	·397
21—	·032	25—	·095	56—	·044	16—	·174	Y —	·404
22—	·028	26—	·103	55—	·050	15—	·175	Z —	·413
23—	·025	27—	·113	54—	·055	14—	·177	A 1—	·420
24—	·022	28—	·120	53—	·058	13—	·180	B 1—	·431
25—	·020	29—	·124	52—	·060	12—	·185	C 1—	·443
26—	·018	30—	·126	51—	·064	11—	·189	D 1—	·452
27—	·016	31—	·133	50—	·067	10—	·190	E 1—	·462
28—	·014	32—	·143	49—	·070	9—	·191	F 1—	·475
29—	·013	33—	·145	48—	·073	8—	·192	G 1—	·484
30—	·012	34—	·148	47—	·076	7—	·195	H 1—	·494
31—	·010	35—	·158	46—	·078	6—	·198		
32—	·009	36—	·167	45—	·080	5—	·201		
33—	·008			44—	·084	4—	·204		
34—	·007			43—	·086	3—	·209		
35—	·005			42—	·091	2—	·219		
36—	·004			41—	·095	1—	·227		

In ascertaining the precise measures of the principal guages, the author has had the valuable co-operation of the Messrs Stubs of Warrington, who manufacture a large number of these guages, and who tested the drifts they employ, by means of a sliding guage constructed by Holtzapffel & Co., for reading off quantities to the thousandth part of an inch, by means of a vernier; the results of these admeasurements are stated in the three sections of the accompanying table.

The three series of measures or guages particularized in the annexed table, have no relation whatever to one another; for

example, the numbers 10 of the table are respectively different and undefined quantities, or are neither aliquot nor direct fractional parts of the inch, as the number 10 notches are severally ·134, ·024, and ·190 of an inch wide; and other similar numbers are also unrelated.

The approximate measures of any one of these three series may, perhaps, be moderately familiar to those artizans who use that particular guage, but these same artizans will probably be as little informed of the two other guages, as the generality of individuals, to whom the whole of these, and other arbitrary ill-defined measures are vague and confused; because their nomenclatures have no relation whatever, either to one another, or to our general standard of such quantities, namely, ordinary linear measure; or in other words, the standard foot and inch.

The following explanatory remarks on the three guages specified in the table, and certain other guages derived from them, will show the complicated and uncertain nature of the subject of measures for wires, sheet metals, and various small works.

1. The first column of the Table refers to the guage used for most kinds of wire, and is thence called for the sake of brevity, the "Wire guage," although it is also known as the "Birmingham wire guage," the "Birmingham iron wire guage," and the "Sheet iron guage." This guage which is specified in the column of the Table headed section one, is the most common of the three principal kinds, and is employed not only for iron wire, as its name implies, but also for brass and other wires, for black steel wire, also for sheet iron, sheet steel, and various other materials, and likewise for some manufactured works, including screws for joiners' use.

On reference to the Table, it appears the largest notch of the Birmingham iron wire guage, is marked 0000, and measures 454 thousandths of an inch, or $4\frac{1}{2}$ tenths of an inch nearly; and further, that the smallest notch, marked 36, measures 4 thousandths, or the 1-250th part of an inch. Although this guage seems only to possess 40 terms, in reality not less than 60 sizes of wire are made, as intermediate sizes are in many cases added; and occasionally, although the sizes are retained, their numbers are variously altered; thus,

The sizes of wires drawn for manufacturing needles correspond with some of the ordinary wire sizes, but the numbers are different; thus No. 1. of the needle wire, agrees with $18\frac{1}{2}$ of the Birmingham wire guage as here shown:—

Needle wires, Nos. 1. 2. $2\frac{1}{2}$. 3. 4. 5. and thence to 21.

And Birmingham wire guage, Nos. $18\frac{1}{2}$. 19. $19\frac{1}{2}$. 20. 21. 22. and thence to 38., are respectively alike.

Sometimes half-sizes of both series are interpolated, and the manufactured needles when bought and sold are designated by another series of numbers unrelated to either of these wire sizes.

Numbers of the Screws.	Numbers of the Wire Guage.	Numbers of the Screws.	Numbers of the Wire Guage.	Numbers of the Screws.	Numbers of the Wire Guage.	Numbers of the Screws.	Numbers of the Wire Guage.
25 —	0000	14 —	3	7 —	9	1 —	15
23 —	000	12 —	4	6 —	10	0 —	16
22 —	00	11 —	5	5 —	11	00 —	17
21 —	0	10 —	6	4 —	12	000 —	18
17 —	1	9 —	7	3 —	13		
16 —	2	8 —	8	2 —	14		

In the wire used for the strings of piano-fortes, the sizes now commonly used, are known as Nos. 6 to 20, and these agree very nearly with the sizes and half-sizes of some of the notches of the Birmingham wire guages, as follows:—

Music wires, Nos. 6. 7. 8. 9. 10. 11. 12. 14. 16. 18. 20.

And Birmingham wire guage, Nos. 26. $25\frac{1}{2}$. 25. $24\frac{1}{2}$. 24. $23\frac{1}{2}$. 23. 22. 21. 20. 19., are respectively alike.

The number 6, or the thinnest music wire now commonly used, measures about the fifty-fifth part of an inch in diameter, and the No. 20, or the thickest, measures about the twenty-fifth of an inch.

Piano-fortes were formerly always strung with brass wire, but steel is now alone employed, and they are "strung much heavier," or thicker wires are employed, from which cause the numbers 1 to 5 have probably fallen into disuse. The covered strings are of steel, upon which a fine copper wire is spirally wound; and in very short strings, as those of Mr Pape's Console Piano-fortes and some others, two covering wires are used, that the bulk of the doubly-covered strings may compensate for their want of length.

The manufacturers of the patent screws made from iron wire for joiners' use, also give the intervals of the wire guage a new system of numbers. Thus in the annexed Table, the left hand columns show the numbers of the screws, the right hand the numbers of the wires from which they are respectively made.

Examples of other and similar conversions of the numbers might be shown, but which would only serve further to illustrate the irregularity, and arbitrary nature of guages, used in the mechanical and other arts.

2. The second column of the Table, refers to the guage employed for most of the sheet metals, (excepting iron and steel), namely, copper, brass, gilding-metal, gold, silver, platinum, &c. This guage is called the "Birmingham metal guage," and for brevity, simply the "Metal guage," or the "Plate guage," in contradistinction to the "Wire guage," specified in the first column of the Table.

The intervals in the metal or plate guage, are closer or smaller than those of the wire guage. Thus the No. 1, which in this series is the *smallest* sized notch, is 4 thousandths or the 250th part of an inch wide, whilst the largest notch or 36, measures 167 thousandths, or is evidently meant for the sixth part of an inch.

When thicker metals are wanted, their measures are sought in the Birmingham wire guage; thus the 36 on the plate guage, nearly agrees with the 8 on the wire guage, and therefore the numbers 7, 6, 5, to 0000 of the latter, are then employed for thicker metals than can be measured by the plate guage. Frequently the plate guage ends at 24, which number agrees with 14 of the wire guage, and then the numbers 13, 12, 11, to 000 of the latter are similarly resorted to for thicker metals. These combinations of different series of numbers, running in reverse orders, are evidently liable to lead to confusion.

The method in which sheet metals are commercially described, also present much variation, for instance zinc has a guage thus constituted—

Sheet zinc Nos. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16.
B. Plate guage Nos. 4. $4\frac{1}{2}$. 5. 6. 7. 8. 9. 10. 11. 12. 13.
are nearly alike.

These thin sheets of zinc, which measure only from one to four hundredths of an inch thick, are principally used for gutters, roofs, and small works manufactured with the hammer.

Thicker zinc plates, or those from about 5 to 18 hundredths thick, and which are used for zincography, door plates, and engraved works, are commonly made to the notches, 18 to 7 of the Birmingham Wire Guage, without alteration of the numbers, but which run the reverse way of those of the other series used for zinc.

Several of the metals are estimated by the weight of every superficial foot, and that the more especially when the value of the material in the sheet, exceeds the value of the labour afterwards expended upon it in converting the metal to its intended purpose; thus

Cast and milled lead are both described as of from 4 to 12 pounds to the superficial foot, the variation being one pound to the foot.

Coppersmiths and braziers, do not acknowledge the plate guage at all, but reckon their metal as from about 3 to 56 pounds to the sheet; the sheet measures 2 feet by 4 feet, and therefore contains 8 superficial feet.

The precious metals, are sometimes estimated as of so many ounces or pennyweights troy to the superficial foot; and it will be hereafter shown, how by aid of the proposed scheme, derived from the decimal subdivision of the inch, the correspondence between the relative weights and thicknesses of metals, may be critically arrived at with great simplicity.

The third, fourth, and fifth columns of the Table constitute one series of guages, employed exclusively for the bright steel wire prepared in Lancashire, and the steel pinion wire for watch and clockmakers.

The smallest notch of this series is called No. 80, and measures 13 thousandths of an inch, or about the 120th of an inch; and the first part of this series continues unto No. 1, which measures 227 thousandths, or nearly one quarter of an inch.

The steel wire guage apparently ended at this size in the first instance, but has since been extended by a second series to the diameter of 494 thousandths, a measure doubtless intended for half an inch. In order to avoid the confusion attendant upon two series of numerals, meeting at zero in the midst, the larger sizes are distinguished by the letters A to Z, and these terms are

then continued under the denominations A 1, B 1, C 1, D 1 to H 1, which latter size is the largest and measures 494 thousandths of an inch, as shown by the Table. This second part of the Lancashire wire guage, is called by way of distinction, the "Letter guage."

Many other guages of arbitrary characters came to the author's knowledge in this inquiry, several of which are applicable alone, to particular trades; amongst these may be mentioned, the rod iron guage, the nail rod guage, the buttonmaker's guage, others used in watchwork, and the guage used by gunmakers for the bores of guns and rifles; three of which guages alone will be described.

The rod iron guage, employed by Messrs Bradleys, and some other iron masters, and also by Messrs Stubs, for steel, has measures derived from the division of the inch into 8ths and 64ths as follows:—

Messrs John Bradley & Co.'s Rod Iron Guage.

No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
00 ——	$\frac{1}{8}$	5 ——	$\frac{5}{16}$	11 ——	$\frac{1}{2}$	17 ——	$1\frac{1}{8}$
0 ——	$\frac{5}{32}$	6 ——	$\frac{11}{32}$	12 ——	$\frac{9}{16}$	18 ——	$1\frac{1}{4}$
1 ——	$\frac{3}{16}$	7 ——	$\frac{3}{8}$	13 ——	$\frac{5}{8}$	19 ——	$1\frac{3}{8}$
2 ——	$\frac{7}{32}$	8 ——	$\frac{13}{32}$	14 ——	$\frac{3}{4}$	20 ——	$1\frac{1}{2}$
3 ——	$\frac{1}{4}$	9 ——	$\frac{7}{16}$	15 ——	$\frac{7}{8}$		
4 ——	$\frac{9}{32}$	10 ——	$\frac{15}{32}$	16 ——	1		

Messrs John Bradley & Co,'s Nail Rod Guage.

No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
00 ——	$\frac{1}{8}$	$1\frac{1}{2}$ ——	$\frac{13}{64}$	4 ——	$\frac{9}{32}$	7 ——	$\frac{3}{8}$
$00\frac{1}{2}$ ——	$\frac{9}{64}$	2 ——	$\frac{7}{32}$	$4\frac{1}{2}$ ——	$\frac{19}{64}$	8 ——	$\frac{13}{32}$
0 ——	$\frac{5}{32}$	$2\frac{1}{2}$ ——	$\frac{15}{64}$	5 ——	$\frac{5}{16}$	9 ——	$\frac{7}{16}$
$0\frac{1}{2}$ ——	$\frac{11}{64}$	3 ——	$\frac{1}{4}$	$5\frac{1}{2}$ ——	$\frac{21}{64}$	10 ——	$\frac{15}{32}$
1 ——	$\frac{3}{16}$	$3\frac{1}{2}$ ——	$\frac{17}{64}$	6 ——	$\frac{11}{32}$	11 ——	$\frac{1}{2}$

It will be perceived that the intervals, from $00\frac{1}{2}$ to $3\frac{1}{2}$ are the 64th of an inch, from 4 to 11 the 32nd, and above 13, the differences are $\frac{1}{8}$ of an inch. This mode although systematic is objectionable, as there is no evident relation between the numbers and their corresponding measures, and therefore both have to be impressed upon the mind.

In guns of most kinds, the weight of the balls determines the denominations of their respective sizes. Thus it is well known that heavy guns or ordnance are named 6. 9. 12 to 68 pounders, from having bores respectively suited to iron shots of those respective weights; the bore is always $\frac{1}{30}$th larger in diameter than the shot, the difference being known as *windage.* The sizes of the bores of mortars and modern guns intended for hollow shot, are designated in inches, as 8, 10, 12 inch mortars, &c.

In rifles and fowling pieces, the diameters of the bores, designated as No. 1, 2, 3, 4, 5, &c., are the diameters respectively of leaden bullets or spheres, of which 1, 2, 3, 4, 5, &c., weigh exactly one pound avoirdupois; and as the subject may have an interest for some of the readers of this volume, the following particulars of the weights of the balls in grains, and of the diameters both of the balls and of the barrels in hundredths of an inch, are transcribed from Mr Wilkinson's guage which he has constructed with great care.

Mr Wilkinson's Guage for Rifles and Fowling Pieces.

Number.	Diameter of Bore in Hundredths.	Weight of Leaden-bullet in Grains.	Number.	Diameter of Bore in Hundredths.	Weight of Leaden-bullet in Grains.	Number.	Diameter of Bore in Hundreths	Weight of Leaden-bullets in Grains.
5	·93	1400	15	·70+	$466\frac{2}{3}$	25	·60+	280
6	·93−	$1666\frac{2}{3}$	16	·69−	$437\frac{1}{2}$	26	·59+	$269\frac{3}{13}$
7	·89	1000	C17 P	·67+	$411\frac{13}{17}$	27	·59	$269\frac{7}{27}$
8	·85−	875	18	·66	$388\frac{8}{9}$	28	·58+	250
9	·81−	$777\frac{7}{9}$	19	·65+	$368\frac{8}{19}$	29	·58−	$241\frac{11}{29}$
10	·79	700	20	·63+	355	30	·57	$233\frac{1}{3}$
M11 P	·77−	$636\frac{4}{11}$	21	·63	$333\frac{1}{3}$	31	·56+	$225\frac{25}{31}$
12	·75+	$583\frac{1}{3}$	22	·62+	$318\frac{2}{11}$	32	·56−	$218\frac{3}{4}$
13	·74−	$538\frac{6}{13}$	23	·61+	$304\frac{8}{23}$			
M14 S	·72−	500	24	·61	$291\frac{2}{3}$			

From the perusal of the foregoing particulars of numerous guages, employed in different branches of mechanical art, it will have been seen that little analogy, on the one hand, but great confusion on the other, exist in such of the guages as have been referred to; and the author will now briefly state the remedy he would suggest to obviate the difficulty in the most simple and inexpensive manner.

SHORT READINGS IN ELECRICITY.

By Mr. R. Smith, Blackford.

IV.

Although electricity may be developed and rendered evident in an endless variety of substances, yet our information as to its actual composition amounts to nothing more than conjectures. The general opinion on this head appears to be, that it is a subtle fluid, of a high degree of elasticity, existing throughout all material substances to some extent. Although totally destitute of sensible gravity, it is capable of producing astounding effects upon solid matter. A stroke of lightning striking the earth, will show its power by tearing asunder the part aimed at; the stoutest trees are split and torn in fragments by the same power, and the most massive buildings and rocks are compelled to yield to its resistless energy.

Experimental research, however, does not afford us any evidence of its materiality, and the sum of our investigations leads us to consider that it moves through the actual substances or pores of matter, with varying degrees of facility; and, according as the permeated matters allow, they are termed conductors and non-conductors.

Du Fay's theory, afterwards followed up by Symmer, is, that all bodies in an unexcited state, contain two distinct electric fluids, equally subtle, elastic, and diffusive, and each repulsive to its own particles, but attractive to the particles of an opposite species. That their forces are equal at equal distances, varying inversely as the squares of that distance. When in a quiescent state, their electric fluids are said to be combined and neutralized, but when excited, there is an excess of one fluid, and the containing bodies are electrified.

If two bodies A. and B., are brought near each other, the fluid in A. will repel that in B., and *vice versa*—the tendency of the fluids to escape in opposite directions causes the bodies to recede from each other; but if the two are oppositely electrified, they have a tendency to unite, and will force their way through the atmospheric medium between them, and come in close contact. The two fluids here treated of, are distinguished by the terms vitreous and resinous, as produced from glass and resin.

The theory of a single fluid was founded by the American philosopher, Franklin. According to his hypothesis, there is but one species of fluid, and the particles of it repel each other with a power diminishing as the squares of their distance apart, their attraction being also conformable to the same law. He further argues that non-electrics are composed of particles of matter and electricity, which neutralize each other. When a rod of glass is excited by friction with a woollen cloth, it receives, in addition to its own natural supply of electricity, a second quantity from the woollen surface, and the latter is thus rendered minus the amount it transfers to the glass. Hence the glass is said to be *over* and the cloth *under*-saturated.

In the former of these theories, it is assumed that there are two species of electricity, the one produced by the friction of glass on a woollen material, and the other by the same action on any resinous substance. But glass and wax thus treated, invariably tend to induce an opposite state of electricity in bodies brought near them; therefore it is impossible to induce one kind of electricity without at the same time involving the production of the other. As an example of this, if a Leyden phial is charged, it is found to contain both kinds of electricity.

Upon the latter, or Franklinean theory, Mr Noad states "To this theory it is objected, that it involves an assumption at variance with the laws of gravitation, namely, that of matter being repulsive to itself. It requires also a repulsive fluid superadded to matter, and freely moveable amongst its particles, to explain satisfactorily the unequal distribution of the electric energy over the surface of the electrified bodies, as well negative as positive, dependent on their form." Hence Dr Turner observes, with this addition the theory of Franklin would virtually cease to be that of a single fluid.†

In a merely hypothetical survey of the subject, either of these theories will answer the end of an explanation of the phenomena attending it. Still, upon a more comprehensive examination of them, we find that they do not afford the readiest means of smoothing down the ruggedness of the paths of electrical science, nor are the terms of explanation deduced from the clearest of vocabularies. As, at any rate, there is ample room for varieties of doctrine, the author ventures to submit the results of his own experiences on this head. These amount to the supposition that electricity is a single fluid, capable of effecting different results under different circumstances. If an insulated metallic cylinder is brought into the vicinity of excited glass or resin, the cylinder or conductor becomes electrified, but, possessing properties differing from those of the electric whence it derives its electricity, it may be supposed that the electric fluid produced by the excited electric, contains different energies blended together, and, on being conveyed to the insulated conductors, these energies are separated and occupy different positions upon it. As an illustration, let us suppose a pith ball to be attached to a silk thread, and held near to the conductor—under these circumstances it is found that the ball is subject to the attracting power at every part of the conductor but the centre. Again, if the ball is excited, it will be attracted at one extremity of the conductor and repelled at the other. Hence, the conductor is not charged in the same degree throughout; its two extremities being widely different from each other, while the centre is neutral. When a Leyden phial is charged, the interior coating contains one of these energies, and the exterior one, the other. The author then proposes to substitute for the terms positive and negative, or vitreous and resinous, names deduced from the different luminosities of the two, as their distinguishing characters.

When a point is presented to a positively electrified body, we know that the appearance of the electric fluid is that of a star, while, on the contrary, a negative body gives forth a pencil or brush of light; thus, it may be urged, that the terms *etole* (star) *energie*, and *pinceau* (pencil) *energie*, are more appropriate than the designations positive and negative, according to the theory of Franklin. When a Leyden jar is positively charged, an equal amount of the natural electricity of the exterior is expelled to the earth; and this is said to be proved by the fact, that it is impossible to charge a jar when insulated. Therefore, when a jar is charged, the interior contains an excess of electricity, while the exterior is deficient in its supply. We may then reasonably suppose that the natural or quiescent electricity of the jar is expelled in consequence of the accumulation of the active electrical energies; the outside being occupied by the *pinceau*, and the inside by the *etole energie*.

When the jar is discharged, the two combine, and in their passage through the dielectric-air, produce the flash and report. As regards material substances, it is impossible to cause two bodies to occupy the same space at the same time, so that, for what we know to the contrary, electricity may resemble matter in this respect, that active and quiescent electricity will not occupy the same place at the same given time. The repulsion of a pith-ball by excited glass, and its attraction by excited wax, were formerly explained according to the theories of Du Fay and Franklin. Let us now endeavour to expound it agreeably to the one under our present consideration; namely, and in the first place, that in no case is the one energy called into action without the simultaneous production of the other; in the second place, that the different energies in both electrics are equal, but that excited glass has the property of communicating first, a small portion of its *etole energie* to other bodies, while wax, on the other hand, sends out its *pinceau* first; although the quantity thus given out is small, yet it may be sufficiently intense to produce an electrifying effect upon small and light substances.

These opposite properties may depend upon the form or construction of the component molecules; even their relative hardness or softness may affect their capacities.

Late discoveries have led us to suppose that light, heat, magnetism, and electricity, are all modifications of the same agency upon matter under different conditions. Light, concentrated by a lens, produces intense heat; passed through a prism, it is separated into various colours, and these colours, like electricity, contain different energies, producing luminous, chemical, and calorific effects; and to venture on the supposition that these are attributable to electricity, is not unreasonable. When an electric current is made to pass round a ray of polarized light in a plane perpendicular to the ray, it causes the latter to revolve on its axis, proving the close connection which light and electricity bear to each other. This discovery alone will serve to transmit the name of its parent, Dr Faraday, down to posterity—a brilliant star in the galaxy of electrical science.

BOGARDUS' ECCENTRIC GRINDING MILL.

Grinding Mills are perhaps the oldest known species of machinery, and yet the principle of their construction has undergone less alteration than any other. No matter what form was given to the mill, the principle of keeping one stone or plate stationary, and causing the other to revolve at a high speed a little above it, has been universally adhered to. Mr Bogardus, an ingenious citizen of New York, has, however, set the example of a judicious departure from this form, by the introduction of the eccentric system, somewhat similar to the motion employed in polishing

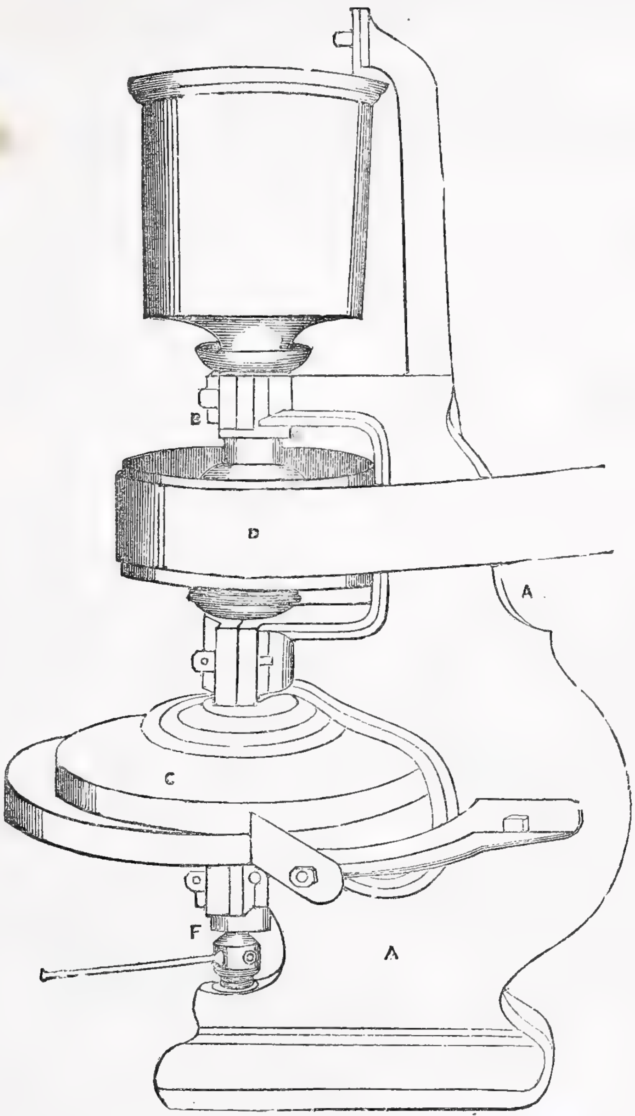
† Noad's Lectures on Electricity.

glass, and by lapidaries in polishing precious stones. The following are some of the advantages of mills worked on this principle :—

1. The peculiar motion of the plates will, of itself, discharge the ground substance, so that many substances can be ground thereby which would altogether choke other mills.

2. In other mills, a given point in one of the plates continually describes the same circle on the other; but in this mill it traverses on the other plate at an infinite variety of angles, every point within two concentric circles apart from each other, twice the distance of the centres of the plates, thereby rendering the wear and tear of the plates uniform, and preserving the grinding action of every point.

3. In other mills, the grinding power of each point increases with its distance from the centre; but in this mill, every point from the centre to the circumference has the same grinding power. A considerably smaller mill will, therefore, effect a given purpose, and the eccentric mill is therefore more portable than other mills.



4. The ever-changing action of the mill, and the quick discharge of the substance ground, prevent it from becoming heated, so that the eccentric mill may be profitably employed in grinding substances which, in other mills, would be either spoiled or deteriorated in quality—or, by their melting, be impossible to be ground. If other mills were driven with that speed which can be safely applied to the eccentric mill, they would be made red hot in a few minutes.

These mills have been successfully introduced for the following purposes :—Hulling rice, coffee, and olives. Grinding grain of all kinds; paints of all kinds, in water or in oil; iron, zink, copper, and gold ores, plumbago and manganese, bones for manure, and bones for refining sugar, flint and quartz, charcoal, plaster, putty, printers' inks, drugs and dye stuffs, snuffs, mustard, coffee, spices, loaf sugar, starch, gums, resins, asphaltum, india-rubber, flax seed, and oil cake, &c. &c.

Of the substances enumerated, some cannot be ground at all by other mills; in short, the eccentric mills are more economical in the power required to drive them, and in the labour of tending them; they are less costly for the work they do, and more portable; they are capable of being applied to purposes for which other mills are useless; and the tear and wear is trifling.

The mill should run to the right, and make not less than three hundred revolutions per minute. Nearly any quantity can be ground by increasing the speed. The mill is regulated to grind fine and coarse by the under-screw, on which the end of the shaft revolves; turning the screw to the left, will bring the plates together and cause the mill to grind finer. The regulating screw is held firmly in any position by a small screw placed against its side. There are three reservoirs, which should be well supplied with oil. The first is on the top of the upper plate: two or three table-spoonfulls of oil should be poured into this reservoir through

a small hole made in the top of the mill for that purpose. The second reservoir is the box, through which the main shaft passes; this is just under the spout of the mill. This reservoir should be filled with tallow so that it may supply itself. There is also a small hole in the back part of the mill, through which oil can be poured into this reservoir, if requisite. The third reservoir is the step in which the main shaft revolves, that may be filled with oil. The feeding is regulated by a shoe acting against the tube of the upper plate, which causes the shoe to vibrate; this, with the slide in the hopper, regulates the quantity fed into the mill. Screw holes are made round the rim of the hopper, for the purpose of extending its size to any dimensions required.

Our engraving represents a front elevation of one of the mills applied by Mr Bogardus to the grinding of moist or liquid substances.

A is an upright cast-iron frame, carrying three projecting brackets as seen at B. The upper revolving plate is seen at C, it is driven by the pulley D, beneath this plate is placed the lower separate revolving plate, at a distance from it to suit the nature of the material to be ground. The centre of motion of the latter plate, is placed about an inch out of the centre of the upper one; it is driven merely by friction generated by the abrasion of the substance in process of grinding between the plates. An adjusting screw F is placed beneath the lower plate for the purpose of setting the latter at the proper distance from the upper plate.

APPARATUS FOR TESTING THE POWER REQUIRED TO WORK MACHINES.

By Mr. James Whitelaw.

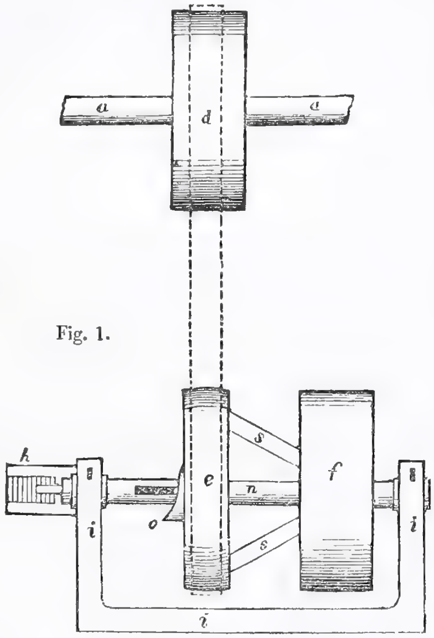


Fig. 1.

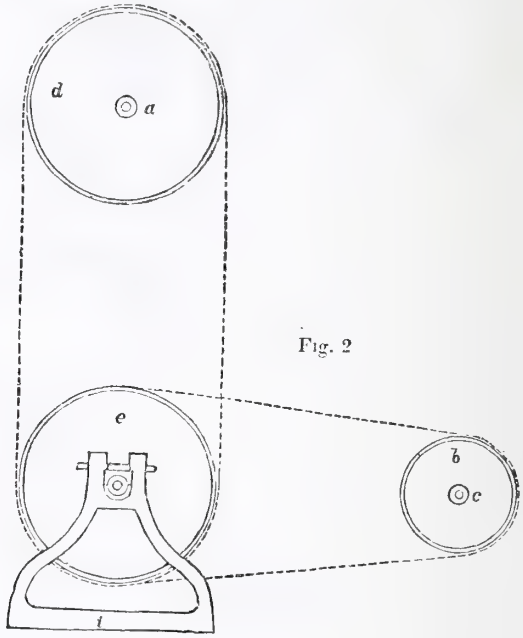


Fig. 2

Fig. 1, is a side elevation; and fig. 2, an end view of an apparatus, by means of which the power required to work most kinds of machines in ordinary use, may be determined. When a part is seen in both figures, the same letters point it out in each.

a a, is the main or the intermediate shaft, and *d* is a drum on it, which, by means of a strap, in ordinary cases, communicates motion to the fast and loose pulleys at *b*, on the driving shaft *c*, of the machine to be tested. Before an experiment is made, the drum *d* must be shifted endlong whichever way may be the most convenient in order to get a strap to work on it that will carry its motion to the pulley *e*, which forms part of the testing apparatus. A strap from the drum *f*, will then be required to keep the pulleys at *b* in motion. The frame *i i i*, into which the pulleys *e*, and *f*, and their spindle *n*, work, is fastened to the floor, or is fixed in some other suitable position. There are collars on the spindle *n*, which prevent the pulley *e* from moving laterally, although this pulley is at liberty to revolve on the spindle. The drum *f* is fixed on the spindle. *s* and *s* are strong springs which transmit the motion of the pulley *e* to the drum *f*. The springs are connected to the pulley *e*, by links, and their other ends are fastened to the drum *f*, in such a way that they will carry it round, although their ends at *e* should be at liberty to move from or towards the spindle *n*. The pulley *e*, and the drum *f*, having each the same diameter, the speed of the pulleys at *b* will be the very same whether they be worked at once from the drum *d*, or whether they receive their motion from the drum *f*.

When the parts, as arranged in the figures, are in motion, the springs will be bent a distance in proportion to the degree of resistance or strain on the pulley at *b*, and consequently the pulley *e* will have turned on the spindle as far as the stiffness of the springs will allow it. But when the pulley *e* turns on the spindle it carries the spiral *o* along with it, and this spiral acts on a pin passing lengthways through the end of the spindle, and thus the outer end of this pin points out on the scale *h* fixed to the frame *i i i*, the degree of resistance.

In cases where the resistance or strain is not uniform, a fly-wheel should be fastened on the spindle *n*, or else the rim of the drum *f* should be cast very heavy. It would be the better way to have, instead of the springs *s* and *s*, a strong spiral spring placed inside of the pulley *e*, which would allow the pulley *e* and the drum *f* to be close together, rendering the machine thereby more compact. The scale *h* may be graduated by fastening the drum *f* to prevent it from revolving, and after this is done, a weight suspended by a rope passing round the pulley *e*, will cause the outer end of the pin, passing through the end of the spindle *n*, to point out the place on the scale where the mark corresponding with that weight should be put, and thus the positions of the marks for the required number of weights may be determined. As the degree of power required to work one kind of machine may be very different from the amount of power required to work a machine of another description—it may be necessary to have a number of spare springs, each differing from the rest in stiffness, in order that a spring, having a degree of strength in proportion to the resistance it has to overcome, may be put into the testing apparatus at any time. The same scale will answer for each of

the springs—the figures on it will, however, require to be multiplied by some quantity in every case except one, in order to find out the amount of strain. As the pulley *e* will not in every case revolve in the same direction, the scale should be graduated both ways from the point on it marked 0, or the straps may be worked open in one case, and crossed in another, in order to cause the pulley *e* always to turn the same way, then the marks on the scale may be placed on only one side of the point marked 0. A number of machines may be tested at the same time.

STIVEN'S EXPANDING BORING TOOL.

This instrument is constructed upon the same principle as the ingenious expanding drill, invented by Mr Yuile, (for a description of which, see vol. ii., p. 301); but possesses some features of superiority over it in its minor details.

Fig. 1 is a front view of the drill, with the top plate of the cutter removed.

Fig. 2 is a view taken at right angles to it, with the plate in its place.

a is the stock of the drill, having a slot planed along its whole length, for the purpose of receiving the bar *b*, which is wedge-shaped at one extremity *c*, for the purpose of forcing outwards the two cutters *d d*, in the direction indicated by the arrows. These cutters are lozenge shaped, and fit into a corresponding recess cut in the stock; thus the action of the wedge, which is inserted between the two, is rendered much easier, and less liable to wear than if their motion was at right angles to the axis of the stock;

Fig. 1.

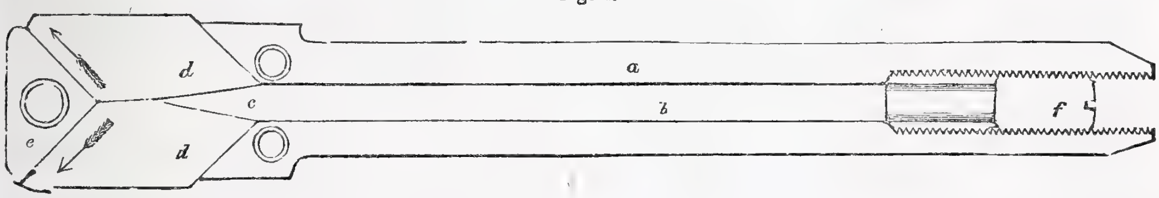


Fig. 2.

they are retained in their places by a plate *e* screwed to the stock by three screws; by this means a sufficient amount of friction is given to them to prevent their falling out edgeway. The method of urging forward the bar *b* in the act of expanding, is by means of the screwed head *f*, which is received into a female-screw in the head of the bar; in this manner, the fastening presents no obstacle to its adjustment in the drill spindle, which may be accomplished by a square upon the block, or by a set screw in the usual manner.

WARREN'S PATENT SCREW-MAKING MACHINE.

Fig. 1.

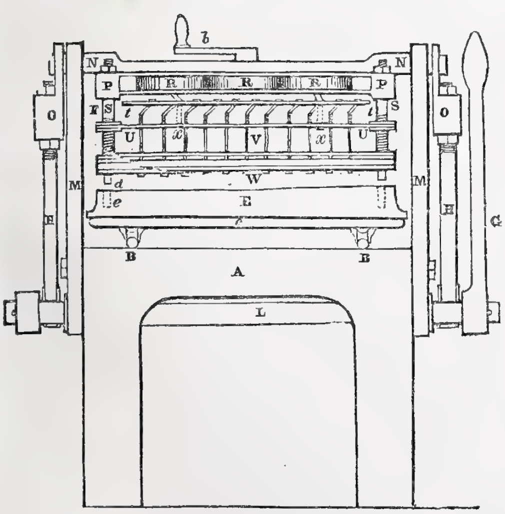
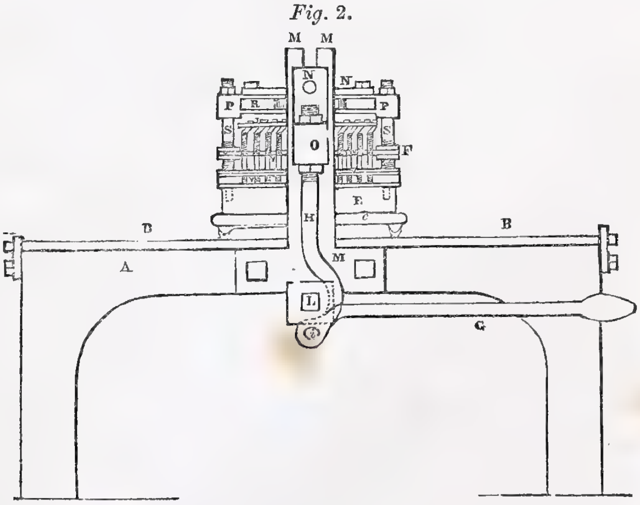


Fig. 2.



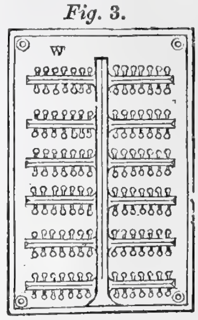
This machine is intended for making cast-iron screws. The general mode of procedure is, to screw patterns of the screws into the moulding-sand, and unscrew them, so as to leave their impressions in it.

Description.—A is the wooden bench upon which the machine is erected; B B, two tramrods fastened to the bench. Upon these the iron plate *c* moves longitudinally, upon four small rollers. E is a moulding-box, resting upon the plate *c*, by which it may be shifted at will. M are two upright iron plates, bolted to the bench, with holes at the lower part to receive the ends of the shaft L, and vertical grooves in the upper part to receive the ends of the lifting-frame N. To this the screwing-frame is

attached, by means of the screw-bolts x. The ends of the lifting-frame are dropped into the grooves in the upper parts of the plates M, and pass through holes made to receive them in the pieces of iron O. These pieces of iron have other plain holes in them, to receive the upper ends of the supporting-rods H, which are screwed in parts, as represented in the drawings; and the elevation of the screwing-frame is regulated by the nuts which work upon them. The lower ends of the supporting-rods H are of a curved form: one of them is connected with the end of the lever G by the round pin i (fig. 2), upon which it works. The lower end of the other supporting-rod is similar, and is connected with a piece of iron of the same form as the lower end of lever G, attached to the other end of the shaft L. By moving the lever G, a similar motion is given to both the supporting-rods, which work upon the ends of the lifting-frame N, and which, together with the screwing-frame attached, are thereby raised or depressed. S, S, are two of four pillars at the corners of the screwing frame, which connect and hold it together, and have upon them adjusting-screws and nuts, to adapt the plates of the screwing-frame to the length of the screws required to be made. The pillars have likewise, at their lower ends, steady-pins, d, which, when the screwing-frame is let down, enter into holes, e, made at each corner of the sand-box to receive them; and thus the sand-box is kept in its true position during the operation of the screwing of the patterns into and out of the sand. P P is an iron frame, which contains the motion-wheels, R, R, R. The middle one is worked by the handle b, and gives motion to the other two. t t, the crank-plate, is a plate of metal containing the holes in which the ends of the cranks of the patterns are inserted, and in which they revolve; and it also contains the holes through which the motion-cranks pass, and in which they revolve, by which motion is given to the crank-plate, and thereby a circular motion is given to the patterns. U U the guide screw-plate, which is also a plate of metal containing internal screws, in which the guide-screws work; and it also contains holes, in which the lower ends of the motion-cranks revolve. V is also a plate of metal, called the steadying-plate, which may be placed either above or below the guide screw-plate. Its use is still further to steady the patterns whilst being screwed into and out of the sand; but it is not essential in making short screws. W is the head-plate, which is also a plate of metal, containing patterns of the heads of the screws; and within them are the holes through which the patterns are screwed into the sand. These three plates last mentioned are let on to the pillars S, S, and fastened by nuts; except that when the steadying-plate is placed above the guide screw-plate, it is not fixed, but travels up and down the pillars, and would be placed immediately above the guide-screws on the patterns. The position of the head-plate is always the same: the position of the steadying-plate and guide screw-plate may be varied, by means of the nuts and adjusting-screws upon the pillars, according to the length of the screws intended to be made. Each of these three plates contains as many holes as there are patterns used in the machine, each set of holes corresponding to each other, so that the patterns are each perfectly perpendicular. Y is a piece of metal, which comprises the crank, the guide-screw, and the pattern-screw, called 'the pattern.' There are as many of these used in each machine as there are screws intended to be made by one action of the machine. The number of patterns to be used in one machine varies according to the size of the screws intended to be made; and they may, or may not, be made with heads upon them. If they be not made with heads upon them, the heads on the head-plate will be unnecessary. These patterns are passed through the holes in the guide screw-plate, the steadying-plate, the crank-plate, and the head-plate; and the guide-screws work in the female screws on the guide screw-plate. The crank-plate has as many holes as the other plates, and they are made to receive the ends of the cranks of the patterns, and to allow them to work and revolve in them, perfectly free and clear of each other. The crank-plate rests upon washers placed upon the cranks of the four corner patterns; and washers are likewise placed above, secured by four small screws, which keep the crank-plate in its right position. x x are the motion cranks. The lower ends revolve in holes made in the guide screw-plate. This plate is held quite firm and steady by the nuts on the pillars. The upper ends revolve in holes in the iron wheel-frame P, and they are fixed to the centres of the outer wheels. The throws of the motion-cranks are the same as the throws of the cranks of the patterns—that is, on being moved round, they describe similar circles. On the motion being given to the wheels by the handle b, the outer wheels give motion to the motion-cranks, which again give motion to the crank-plates; and all the cranks of the patterns inserted in them are caused to move round. The guide-screws are thus made to work in the female screws in the guide screw-plate; and the crank-plate and the patterns are also drawn down and depressed, and the screw-patterns made to screw out and project beyond the holes in the head-plate. By reversing the motion of the handle, the patterns are screwed back into the machine.

The process of moulding is this:—There is a moulding head-plate, gitted and sprayed in the usual manner for castings, which is a fac-simile of the head-plate in fig. 3, where the gitting and spraying is shown, except that the patterns of the heads are solid, and have no holes in them. This plate is placed in the sand-tub, and upon it is placed the iron box E. This box is then filled with sand, which is slightly pressed. A board is then laid upon the top of the box, in the usual way; and when turned over, there will be upon the upper part of the sand the impressions of the heads of the intended screws, as also of the gits and sprays. The box E is then placed upon the iron plate C, with the impressed side upwards. The iron plate C is then rolled under the screwing-frame. By means of the lever G, the screwing-frame is lowered, and pressed firmly down upon the box E, and there kept steady. Upon this being done, the patterns upon the heads of the screws, and the gits and sprays upon the head-plate W, precisely fit into the impressions in the sand which have been already made by the moulding head-plate. The pattern-screws are then screwed in and out of the sand by the operation before described. The screwing-frame is then raised by means of lever G, and the box E is drawn out again, and the impression of the screws in the sand will be found perfectly accurate. A surfaced moulding-plate of iron is put into the sand-tub, upon which another moulding-box, of the same description as E, is placed, and filled with sand. A board is then placed thereon, as before, upon box E; and the box being turned over, a smooth surface of sand will be found, corresponding in size to the surface of box E. This surface is then placed against the impressed surface of the sand in box E, and they are screwed together by wooden screw-clamps, and together form the mould. The mould is then placed upon its end, with the mouth upwards, into which the hot metal is poured. When the boxes are separated, the screws will be found perfect, except as to the nick or slit on the heads, which may be made in the usual way with a circular saw, or the nicks may be also moulded, if thought better.

Fig. 3.



THE COMBINATION OF THE TELESCOPE WITH THE DAGUERREOTYPE.

An interesting subject for inquiry has lately occupied the attention of the Royal Society of Bohemia, that is, the application of the telescope combined with the daguerreotype, to astronomical observations. Prof. Doppler says, that notwithstanding the extreme susceptibility of the human eye, it is surpassed many thousand times by an iodized daguerreotype plate. Physiological experiments have shown, that objects which appear to us under an angle of vision *less* than 50 or 40 inches, are no more seen *in extenso*, but as *amorphous* simple points. On the other hand, physiological researches of such men as Muller, Weber, &c., have shown, that the diameter of one of the nerve papillæ of the retina is no more than $\frac{1}{4800}$ or $\frac{1}{8000}$ of an inch. But comparing the susceptibility of the retina papillæ with the microscopic experiments made with Daguerre's plates, it will follow that the single globules of mercury are of such extreme minuteness, that they become only visible by an 800-fold magnifying power; and therefore, that on the space of a Daguerre plate, equal to one retina papilla, more than 40,000 single minute globes of precipitated mercury are to be met with. Each of these is capable of producing the image of well-defined objects—which would merge on the human retina in

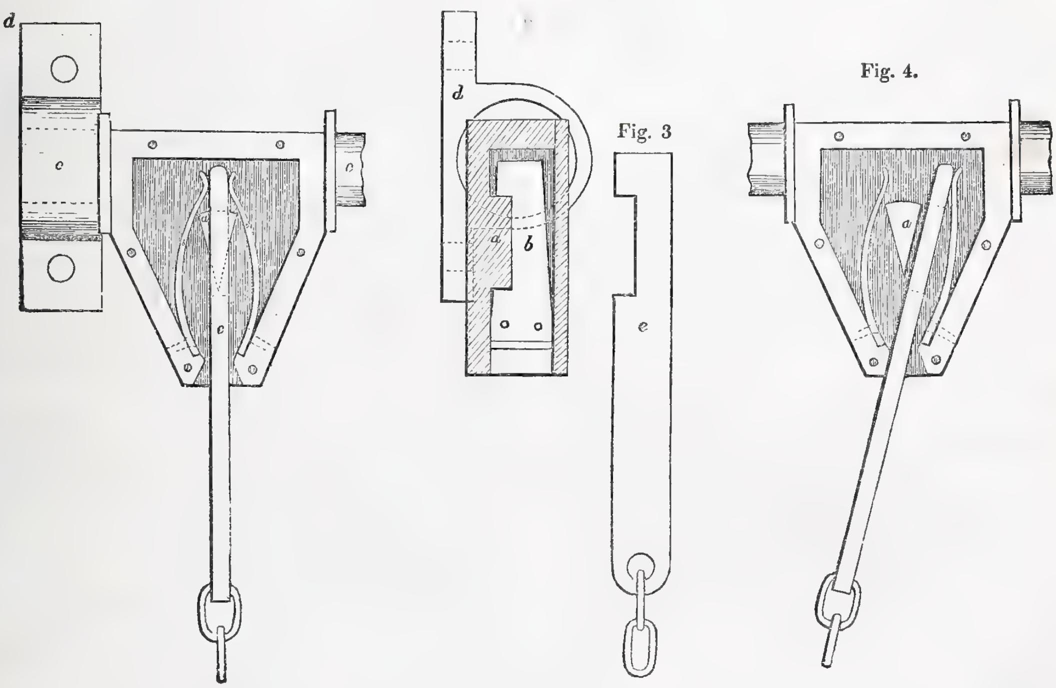
single, indiscernible luminary points. Thence Prof. Doppler argues, that Daguerre's plates are 40,000 times more susceptible for impressions than the human eye.

Considering, moreover, that a great improvement in microscopes is very probable, M. Daguerre thinks that, instead of telescopes, microscopes will come into use. At the exact point, therefore, where the image of a celestial body is formed before the object-lens of a telescope of considerable length, an apparatus is to be placed, whereby a silver plate (iodized, brome-iodized, or otherwise prepared) can be securely inserted. As the place of the images is the same for all celestial objects, a plate of a well-defined constant thickness can be inserted with great accuracy. In this way daguerreotype images of all, even of the smallest, fixed stars can be obtained, if (as is to be supposed) the light will be sufficient to affect the plates. It is also to be taken into account, that the images of the fixed stars, obtained by an object-lens of from 10 to 12 inches, will possess a light 10,000 times stronger than they present to the naked eye. Plates thus affected are to be treated with mercurial vapours and laved (*lavirt?*), and then viewed by a good microscope. As these images will have been magnified (through the action of an object-lens—say of 110 inches focus length) to the extent of 14 times their natural appearance, and being again magnified 1200-fold, the angle of vision under which they are now to be viewed will have been increased 16,800-fold.

SAFETY COUPLING-BOX FOR RAILWAY TRAINS.

The occurrence of serious accidents on railways, arising from the engine running off the line, renders it desirable that some simple means should be devised for instantly disconnecting the engine and tender from the train, when such an occurrence takes place. Many accidents of this kind might have been much more disastrous, had not the coupling irons given way, connecting the train with the tender. The train is sometimes thus allowed to remain on the rails; and what we would suggest is, that that which occasionally takes place

Fig. 1. Fig. 2. Fig. 3 Fig. 4.



by a happy accident should in future be insured by a simple self-acting mechanical contrivance, which shall unlock the train from the engine the moment that the latter shall happen to leave the rails. A scheme of this kind was devised by Mr. S. B. Howlitt, of the Ordnance Office, so early as 1840, and was described and illustrated in the fourth volume of the Professional Papers of the Royal Engineers. We take the liberty of reproducing this plan, as it appears to be simple, and might be rendered efficient.

Fig. 1 is a cast-iron box, shown in plan, consisting of sides and bottom; the top, consisting of a separate plate bolted to the box, being removed to show the arrangement of the parts in the interior. Externally, it is provided with trunnions which turn in sockets bolted to the front of the carriage. The draw-bar which proceeds from it is connected by short link-work to the tender.

Fig. 2, A longitudinal section of the box through the middle of fig. 1, showing one of the sockets behind.

Fig. 3, A side-view of the draw-bar detached.

Fig. 4, A representation of the position of the draw-bar when the chain is pulled sidewise: in this position the bar can be drawn out with ease, and the connection thus broken.

Fig. 5. An isometrical sketch of the coupling-box, supposed to be fixed on the front or lower part of the luggage truck or first carriage; or it might be fixed underneath, the construction being adapted for either position. The end of the draw-bar is broken off in the figure for want of room.

Literal References.—*a*, is the boss or projection cast on the sole of the box, the use of which is to afford a holding surface to the end of the draw-bar.

b, *b*, springs rivetted at one end to the walls of the box, near the opening in front; they reach beyond the boss *a*, and embrace the end of the draw-bar, (when engaged with the boss), the object of which is to retain it exactly in its place.

c, *c*, the trunnions, cast one on each side of the box, upon which the box turns as on hinges.

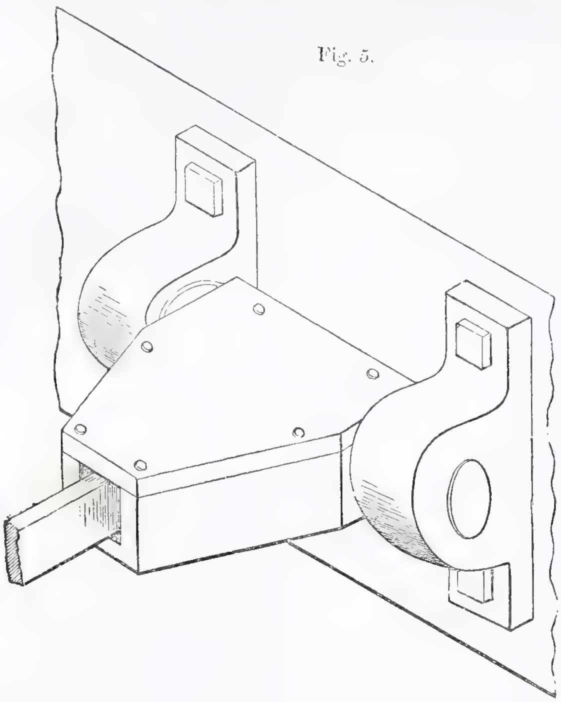
d, one of the sockets, of which there are two, in which the trunnions turn; the sockets are bolted to the carriage.

e, the draw-bar, formed on its under-side with a notch, which slips over the boss *a*, when the bar is introduced into its place, and is held in that position by the springs.

It is obvious that no direct pull could withdraw the bar, because

the notch rests over the boss, and the bar being held by the springs, cannot shift its position laterally without a greater lateral force being applied than could occur by shaking while travelling. The office of the springs is simply to hold the bar over the centre of the boss, and should, in the manufacture, be adjusted accordingly; they should, in fact, be of such a strength that a man laying hold of the end of the bar and pulling it as a lever against either side of the entrance, should be just able to open either of the springs and release the bar. The entrance of the box is wider than the bar,

Fig. 5.



sufficiently to allow for ordinary deviations from the middle position.

Mr Howlett proposes the application of this safety-coupling between the tender and the first waggon of the train. We think, however, that it might be applied between the engine and the tender, so as to leave the tender, as well as the train, on the line. Our principal object in proposing this is to provide likewise for the safety of the driver and stoker on the platform. A simple modification of the existing arrangement of the platform would, however, be necessary to effect this most desirable end: for, according to the presently arranged method, one-half of the platform is erected on the engine, the other half on the tender. Now, as the engine and tender are constantly linked together as one, we see no difficulty in the way of attaching the whole of the platform to the tender-frame. Thus, while the men could have a complete command over the engine, they would be independent of it for foot-hold; and if it ever started aside and left the tender and train, it would go alone to destruction. We do not forget that another connection subsists between the engine and tender, namely, the flexible tubes which convey the water from the tender to the force-pumps. These would, however, very easily give way if no other connection remained. But, at all events, it would not be a difficult matter to construct the water-tubes with sliding joints, which should part asunder of their own accord when the engine leaves the tender. The railing with which the platform is enclosed at the sides might be carried round the front of it close to the engine, leaving an opening, of course, for firing; this would prevent the possibility of the driver or stoker being precipitated from the platform at the moment of the accident. The application of Mr Howlett's coupling-box would, in this case, likely require it to undergo some modification. We recommend the principle of the complete isolation of the engine to the consideration of railway engineers, who will best understand the value of what we have now stated. The utility of the idea, apart from the readiness with which it might be applied, is as clear as disastrous occurrences can make it, when we know that these occurrences would have been greatly alleviated had the arrangements which we propose been applied. While we would hail with pleasure the progress of steam locomotion, we would also insist on the corresponding advance of precautionary measures against accident, and would aid in the furtherance of this object as far as our humble suggestions can go.

AN ACCOUNT OF THE PROCESSES EMPLOYED IN THE ASSAY OF GOLD AND SILVER COINS AT THE MINT OF THE UNITED STATES.

By the Director of the Mint.

ASSAY OF GOLD COINS.

Principles of the operation.—According to law, the standard gold of the United States is so constituted, that in 1000 parts by weight, 900 shall be of pure gold, and 100 of an alloy composed of copper and silver.

The process of assay requires that the copper and silver be both entirely removed from the gold; and to effect this, two separate operations are necessary.

The first is for the removal of the copper; and this is done by a method, of very ancient date, called *cupellation;* which is conducted in an assay furnace, in a cupel composed of calcined bones, and by the aid of lead. It is founded on the property which this metal possesses of oxidizing and vitrifying under the action of heat; of promoting, at the same time, the oxidation of the copper; and of drawing with it, into the pores of the cupel, the whole of this metal, so as to separate entirely this part of the alloy, and to leave behind the gold and silver only.

The separation of the silver from the gold is effected by a process founded on the property possessed by nitric acid, of dissolving silver without acting upon gold. That this may be thoroughly accomplished, it is found necessary that there be an excess of silver over the gold, as otherwise the latter metal will cover and protect the silver from the action of the acid. Experience has shown that the silver present should be about three-quarters of the whole mass—a condition which has given to the process the name of *quartation.*

Process of assay.—The reserved gold coins under trial are melted together and cast into a bar, from which a suitable piece is taken, flattened by a hammer, and rolled into a strip. From this strip pieces are cut, which, together, shall weigh exactly 1000 units. At this Mint, the unit weight employed in the assay of gold is *half a milligramme;* so that the whole weight submitted to assay is a *half gramme,* or about 7·7 grains.

Silver is next weighed out for the quartation; and as the assay-piece, if standard, should contain 900 units of gold, there must be three times this weight, or 2700 units of silver; and this is accordingly the quantity used. It is true that there is already some silver in the alloy, but a little excess over the quantity required for the quartation does no injury to the process.

The lead used for the cupellation is kept prepared in thin sheets, cut into square pieces, which should each weigh about ten times as much as the gold under assay.

The lead is now rolled into the form of a hollow cone, and into this are introduced the assay-gold and the quartation silver, when the lead is closed round them, and pressed into a ball.

The furnace having been properly heated, and the cupels placed in it, and brought to the same temperature, the leaden ball, with its contents, is put into one of the cupels, the furnace closed, and the operation allowed to proceed, until all agitation has ceased to be observed in the melted metal, and its surface has become bright This is an indication that the whole of the lead and copper have been converted into oxides and absorbed by the cupel.

The cupellation being thus finished, the metal is allowed to cool slowly, and the disk or *button* which it forms is detached from the cupel.

The button is then flattened by a hammer; is annealed by bringing it to a red heat; is laminated by passing it between rollers; is again annealed, and is rolled loosely into a spiral or coil called a cornet. It is now ready for the process of quartation.

For this purpose, it is introduced into a matrass containing about $4\frac{1}{4}$ ounces of nitric acid, at from 20 to 22° of Baume's hydrometer; and in this acid it is boiled for 20 minutes as indicated by a sand-glass.

The acid is then poured off, and about half the quantity of stronger acid, at 32°, is substituted for it, in which the gold is boiled for 10 minutes.

This second acid is then also poured off, and another equal charge of acid of the same strength is introduced, in which the gold is kept for 10 minutes longer.

It is then presumed that the whole of the silver has been removed, and the gold is taken out, washed in pure water, and exposed, in a crucible, to a red heat, for the purpose of drying, strengthening, and annealing it.

Lastly, the cornet of fine gold thus formed is placed in the assay balance, and the number of units which it weighs expresses the fineness of the gold assayed, in thousandths.

Test Assay.—To test the accuracy of this process, and to correct it if not exact, the following method is employed.

A roll of gold, of absolute purity, which has been kept under the seal of the Chairman of the Assay Commissioners, is opened in their presence, and from it is taken the weight of 900 units. To this are added 75 units of copper, and 25 of silver, so as to form, with the gold, a weight of 1000 units of the exact legal standard.

This is passed through the same process of assay as the other gold, and at the same time. After the assay is finished, it is evident that the pure gold remaining ought to weigh exactly 900 units. If, however, from any cause, it be found to differ from this weight, and, therefore, to require a correction, it is assumed that the same correction must be made in the other assays, and this is done accordingly.

ASSAY OF SILVER COINS.

Principles of the operation.—The standard silver of the United States is so constituted, that of 1000 parts by weight, 900 shall be of pure silver, and 100 of copper.

The process of assay requires that the exact proportion of silver in a given weight of the compound be ascertained, and this is done by a method of recent date, invented by Gay Lussac, called the *humid assay*, which may be explained as follows:—

The silver and copper may both be entirely dissolved in nitric acid; and if to a solution thus made, another of common salt in water be added, the silver will be precipitated in the form of a white powder, which is an insoluble chloride, while the copper will remain unaffected.

Now, it has been ascertained that 100 parts by weight of pure salt will convert into chloride of silver just 184·25 parts of pure silver. Consequently the quantity of salt necessary to convert into chloride 1000 parts of silver, is 542·74; as found by the proportion,

$$184{\cdot}25 : 100 :: 1000 : 542{\cdot}74.$$

A *standard solution* of salt is accordingly so prepared, as that a certain volume of it, (the *decilitre*), measured in a glass vessel constructed for the purpose, (called *the large pipette*), shall contain 542·74 unit-weights of salt, and be therefore capable of precipitating, in the state of chloride, 1000 units of silver. The unit-weight employed at the Mint, for silver assays, is the French *milligramme*, a thousand of which, or the *gramme*, correspond to about 15·4 grains.

To precipitate *one* unit of silver, it is evident the one-thousandth part of the above measure of the standard solution would be required. But as this volume would be inconveniently small, it has been deemed proper to increase it ten-fold, by the use of what is called the *decimal solution*, which is made by adding to any portion of the former nine times its volume in water, and thus reducing its strength to one-tenth. This decimal solution is used in finishing the assays, and the portions required for precipitating units-weights of silver are measured by a graduated glass tube, called *the small pepette.*

In the mode of assay under consideration, it is necessary that the portion of the alloyed silver used shall contain, as nearly as may be, 1000 units of pure silver. The rigid standard requires, that of 1000 parts by weight, 900 shall be of pure silver; but the law allows a variation from this ratio, provided that it do not exceed three thousandths. The fineness may, therefore, be as low as 897, and as high as 903. In the practice of the assay, it is found most convenient to assume the lower extreme. Now, the weight of metal, of the fineness 897, which would contain 1000 units of silver, is 1114·83; as found by the proportion,

$$897 : 1000 :: 1000 : 1114{\cdot}83$$

The nearest integer to this number is employed, and the weight of metal taken for the assay is 1115.

Process of Assay.—The reserved silver coins under trial being melted together, a portion is cut off from the bar, and is flattened and rolled into a thin strip, in order to facilitate the weighing and the solution. From this strip the weight of 1115 units is taken, and is introduced into a glass bottle with nitric acid, in which it is completely dissolved.

Into this solution the large pipette-ful of standard solution of salt is introduced, and it produces immediately a white precipitate, which is chloride of silver, and which contains of the metallic silver 1000 units.

To make this chloride subside to the bottom of the vessel, and leave the liquid clear, it is necessary that it be violently shaken in the bottle; and this is accordingly done, by a mechanical arrangement, for the necessary time.

Unless the coins have chanced to be below the allowable limit of standard, the liquid will still contain silver in solution, and accordingly a portion of the decimal solution is introduced from the small pipette, capable of precipitating a unit (and sometimes two or more) of silver, and a white cloud of chloride will show itself. The liquid is again shaken, and cleared; and the process is thus repeated, until the addition of the salt water shows only a faint trace of chloride below the upper surface of the liquid.

Let us suppose, for the sake of an example, that three measures of the decimal solution have been used with effect. This will show that the 1115 units of the coin contained 1003 of pure silver; and thus the proportion of pure silver in the whole alloyed metal is ascertained.

Test Assay.—For the foregoing process to be exact, it is necessary that the saline solution be of the true standard strength, or be such that the quantity of it measured in the large pipette shall be just sufficient to precipitate 1000 units of silver. This cannot be assumed without proof; and a test assay is accordingly made, as follows, by which the other assays may either be confirmed or corrected.

A roll of silver, known to be of absolute purity, is kept, from year to year, in an envelope, under the seal of the chairman of the Assay Commissioners. This being opened in their presence, a portion of the silver is taken, and 1004 units carefully weighed off, and submitted to the process of assay described above. If the salt water used be of the exact standard, it is evident that as the solution in the larger pipette will precipitate 1000 parts of silver, four measures of the decimal solution will be required to precipitate the remaining four parts, and if this prove to be the fact, the other assays are confirmed. But if the measures of the decimal solution required fall short of four, by any number, it is evident that the same number must be added to the other assays; and if, on the contrary, the measures required exceed four, by any number, the same number must be subtracted from the other assays.

Calculation of Fineness.—By the assay, thus corrected, the number of units of silver contained in 1115 units of the metal under trial, is ascertained; and the fineness, in thousandths, is is then found by the proportion: As 1115 is to the number of units of pure silver, so is 1000 to the fineness of the alloyed silver, in thousandths.

Thus, if the assay show the presence of 1005½ parts of pure silver, the fineness of the alloyed silver will be 901·8 thousandths, as found by the proportion,—

$$1115 : 1005{\cdot}5 :: 1000 : 901{\cdot}79.$$

It is on this principle that the following table is constructed. The numbers at the top and the fractions at the side correspond to the measures of the decimal solution used, corrected by the test assay. The numbers in the body of the table show the corresponding fineness of the assay-piece, of which the weight was 1115 units.

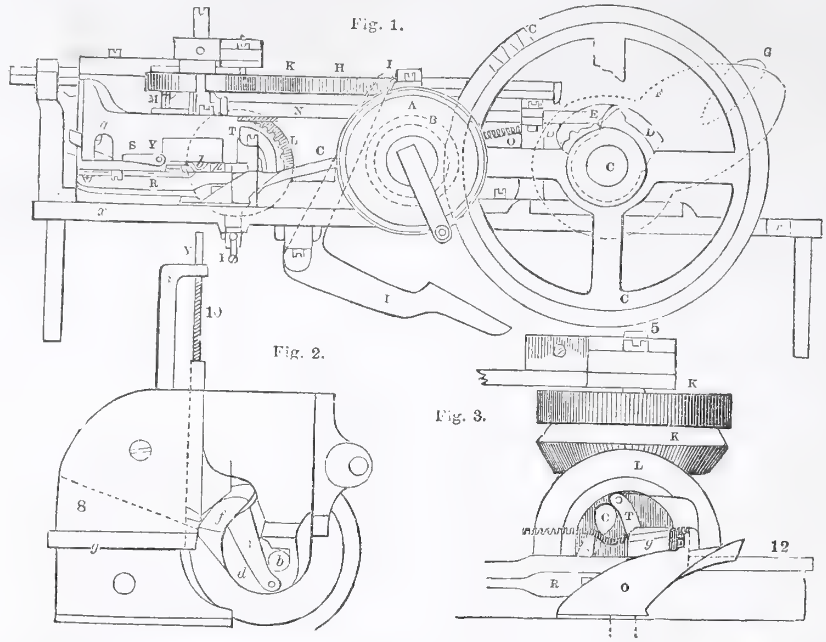
	0	1	2	3	4	5	6
0	896·9	897·7	898·6	899·6	900·4	901·3	902·2
¼	897·1	898·0	898·9	899·8	900·7	901·6	902·5
½	897·3	898·2	899·1	900·0	900·9	901·8	902·7
¾	897·5	898·4	899·3	900·2	901·1	902·0	902·9

MACHINE FOR MAKING CHAIN LINKS.

The annexed engravings are views of an improved machine for making chain links, for which a United States patent was granted to Arcalous Wyckoff on the 14th of last February.

Fig. 1 is a side elevation of the machine; fig. 2 is a detached view, exhibiting, on the under side, the cutter and bender of the wire in the horizontal movement thereof; and fig. 3 is a detached view of a portion of fig. 1, to show the action of the vertical bender, sleeve, and lever, giving the middle bend of the link. Similar letters refer to like parts on the three figures.

The nature of this improvement in machines for making



chains, consists in giving the grip and middle bend of the link, cutting the wire the requisite length, and bending both ends thereof simultaneously, and, by an automatic movement, delivering the formed link ready for joining in a continuous chain.

In fig. 1, *x x* represents a solid table. A is the pulley to which the power is applied, carrying on its shaft a pinion, B, giving motion to the driving wheel, C, on shaft, C; D and E are cams on the horizontal shaft, C, for operating the bars, O and N; F is a large cam, also on the shaft, C, which, striking against the end of the bar-carrying rack, H, gives an intermittent motion to the pinion, K, placed on a vertical shaft, which also carries a bevil pinion (placed under K for giving motion to L, carrying a sleeve), on the outer end of which is a bending arm, which in its semi-revolution forms one eye of the link; M is a pinion (driven by K) which is placed on a vertical shaft, and also carrying a sleeve, on the end of which is secured the knife or die, *f*, for cutting the wire into suitable lengths, and likewise for bending the other eye of each link; O is a bar moved by cam, E; it operates a lever, R, for giving the middle bend to the link, and holding or clamping the wire while being cut by *f*, and stationary die, *g*, also retaining it until the link is formed; N is a bar moved by cam, D, operating the pinion, M, by striking a stud while the wire is cutting; P is a gauge (operated on by a set screw) for graduating the pressure of the angular end of the slide bar, O, on the lever, R, in giving the middle bend and grip to the link; Y is a sliding bar for closing the opening 8, fig. 2, through which the wire is fed; it is pressed by the back of the cutter, *f*, which contracts the helical spring, 10, on the shank of Y; this spring reacts the moment the pressure is removed, and the bar, Y, is forced back and closes the opening, 8, while the eyes of the link are forming; T T are small flat springs, having stub bolts or pins working in incline grooves in the ends of the sleeves or pinions, M and L; they are for the purpose of throwing off the link formed on the mandrils, *c* and *b*. The mandril, *b*, is the one around which the end of the wire is carried horizontally by the die, *f*, in forming one eye; *c* is the mandril around which the wire is carried vertically by the bender on the sleeve of L, simultaneously with the formation of the other eye on *b*; G is a cam secured on the side of cam, F, and in its revolution operating on lever, I, draws back the rack, H, giving a reverse movement to all the pinions except B; the rod, Y, being moved by the back of the die, F, permits the wire to be fed in opening, 8.

The operation is as follows:—A wire being introduced in opening, 8, and held at a slight angle, is forced against the adjustable stop, 12, passing through a guide near to that side. The angular projection, 4, on lever, R, is brought to bear diagonally on the wire, and forcing it up between the pins, *c* and *b*, by means of cam, E, operating on bar, O, and forcing the angular projection thereon under the lever, R, raises it, and thus gives the middle bend to the wire, and securely clamping it between the pins and against the plates. The die, *f*, is now moved by the semi-revolution of pinion, M, acted on by bar, N, and cam, D, and cuts off the wire rod the requisite length for a link, at the same time carrying it horizontally around the pin or mandril, *b*, while the bender on the sleeve of pinion, L, simultaneously carries the other end round the pin, *c*; L receiving its motion from the mitre wheel under K, said wheel being actuated by the sliding rack, H, and cam, F, and completes the link. The springs, T T, are now forced outwards by the pins working in incline grooves on the ends of the sleeves, and thus slide the eyes off the pins or mandrils, *c* and *b*, and the link drops from the machine ready for joining, which may be done by closing the eyes by hand, but much more perfectly by machinery.

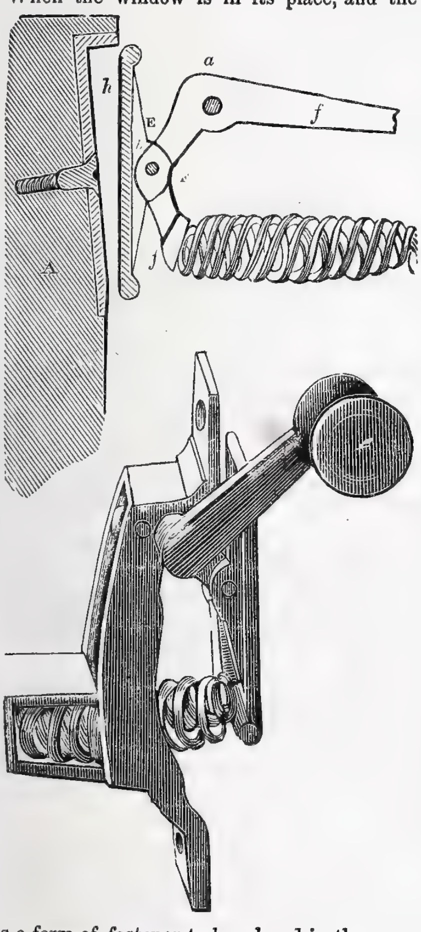
This machine is stated to be now in operation at Columbus, Ohio, U. S. It makes about sixty links per minute, or fifteen hundred pounds per day, and bends them ready for use.

SASH STOPPER AND FASTENER

These accompanying two figures are views of two modifications of a sash stopper and fastener for windows, for which a patent has been granted, in the United States, to J. B. S. Hadaway.

The nature of the invention consists in constructing a sash fastener by the combination of a rocking plate, spiral spring,

and levers, the plate and spring being acted upon in such a manner by a lever, that the window sash can be secured and maintained at any desired point. A, fig. 1, is that part of the case of a window against which the sash abuts. In this part of the case, small inclined metal plates, *h*, are set in at one or more points. These form recesses, notched at the upper part. E is what is termed a rocking plate; it forms the catch to project into the recesses in the case, and to be held therein by the tension of the spiral spring, F. *ff'* is a peculiarly formed small lever; it is secured to the plate, E, by a pivot pin, *b*, passing through ears, and is inserted into a recess in the sash of the window, or a small metal box—that is, plate E, lever *ff'*, and spiral spring F, form the fastener, and are connected together and inserted into the sash, with the rocking plate opposite that part of the case in which the notched plates, *h*, are inserted. When the window is in its place, and the fastener secured in the sash, the tension of the spring, F, pushes the plate, E, to to make it take into the recess formed by the plate, *h*, and prevents the window from being moved. There is a pin inserted into the lever, *f*, at the point, *a*, forming the fulcrum of the lever part, *f'*. By depressing the lever, *f*, by pulling on the lever arm, *f'*, the upper part of the plate will be made to assume the flush position now shown, and allow the window to be raised. There is a small handle with a small cam head inserted into the sash, for elevating and depressing the arm, *f'*, to raise the window. The spring, F, keeps the plate, E, in place in the recess. Fig. 2 is a form of fastener to be placed in the case or frame, the recess plates, like *h*, being placed in the face of the sash. *e* is a handle, and E is the rocking plate to press into the recess, *h*, like fig. 1. The lever of the handle, *e*, forces the spring back from pressing the plate, E, into the said recess, and thus relieves the stopper, so as to move the window up or down. The face of plate E is lined with leather or india-rubber, to prevent marking the inside face of the window frame.



THEORY AND PRACTICE OF NAVIGATION.

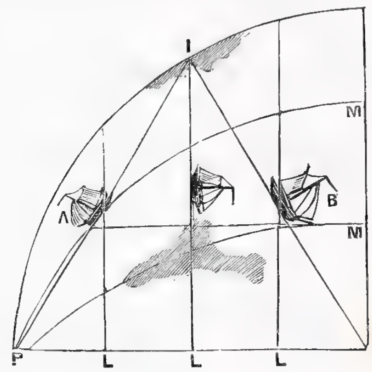
CHAPTER III.

PARALLEL SAILING.

THE figure of the earth being spherical, the meridians gradually approach each other, and meet at the poles. The *difference of longitude* between any two places is the angle at the pole contained between the meridians of these places, or it is the arc of the equator intercepted between the meridians of the given places; and the *meridian distance* between two places, in the same parallel of latitude, is the arc contained between their meridians.

It hence follows, that the meridian distance, answering to the same difference of longitude, is variable with the latitude of the parallel upon which it is reckoned; and the same difference of longitude will not answer to a given meridian distance, when reckoned upon different parallels.

Parallel Sailing is, therefore, the method of finding the distance between two places lying in the same parallel, whose longitudes are known; or to find the difference of longitude answering to a given distance, run in an east or west direction.



The above diagram represents a section, or one-fourth part, of the earth. M M are meridians, which meet at the pole, P; and L L are parallels of latitude. In the diagram, two ships, A and B, are represented starting from the same point, I, say 20° N.; and suppose the ship, A, to sail to 30° N. and 10° W., and the ship, B, to sail to 10° N. and 10° W.; it will be evident that the ship, B, sails a greater distance than the ship, A, before they both come to the same meridian.

From this it will be evident, that the miles in the degrees of longitude decrease as a ship proceeds north, and increase till it arrives at the equator. It hence follows, that the meridian difference of longitude is variable with the latitude.

This sailing will be found most useful when running on any given course, east or west, or bearing down on points of land, or finding the number of miles contained in a degree at any given parallel of latitude.

To find the number of Miles in a Degree of Longitude, at any Degree of Latitude, and in what Latitude a given number of Miles make one Degree of Longitude.

Example 1.—How many miles are in a degree of longitude in latitude 50° 37′ ($4\frac{1}{2}$ points)?

As radius, - - - - - - -	10·00000
Is to cosine of latitude $4\frac{1}{2}$ points, - - -	9·80244
So is miles in a degree at equator, 60, - -	1·77815
	11·58059
	10·00000
To the miles in given latitude 38, - =	1·58059

Solution by Cameron's Mathematical Rule.

Set the rod, C, to the given latitude 50° 37′ ($4\frac{1}{2}$ points), on the quadrant, A; then set the rod, F, to cut 60 (miles in a degree on the equator) on the rod, C; and on B will be given 38, the answer.

Example 2.—In what latitude are 35·5 miles equal to one degree of longitude?

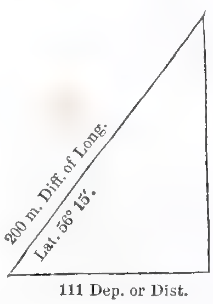
As one degree on equator 60, - - -	1·77815
Is to the distance on required 35·5, - -	1·55023
So is radius, - - - - - - -	10·00000
	11·55023
	1·77815
To cosine of latitude 53° 16′ = $4\frac{3}{4}$ points,	= 9·77208

Solution by Cameron's Rule.

Set the rod, F, to 35·5 on B; then move the rod, C, till F cut 60 on it; and the latitude required, 53° 16′, or $4\frac{3}{4}$ points, will be given on the quadrant, A.

Given the Difference of Longitude between two places, both in one Parallel of Latitude, to find the Distance between those places.

Example.—A ship sails from latitude 56° 15′ N., directly west, till she has differed her longitude 3° 20′.—What is the distance sailed?



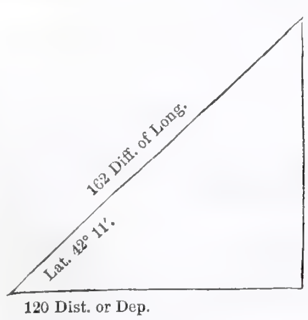
Difference of longitude, 3° 20′, = 200 miles.	
As radius, - - - - - -	10·00000
Is to cosine of latitude 56° 15′ (5 points), - - -	9·74474
So is the difference of longitude 200, - - - -	2·30103
	12·04577
	10·00000
To the distance sailed, 111, - - - - - -	= 2·04577

Solution by the Mathematical Rule.

Set the rod, C, to the latitude 56° 15′ (5 points), on the quadrant, A; then move F to cut 200 (difference of longitude) on C; and 111, the distance, will be given on B.

Given the Distance between two places, both in the same Parallel of Latitude, to find the Difference of Longitude.

Example.—A ship sails due west 120 miles, from latitude 42° 11′ S., and longitude 14° 18′ W.—What is her present longitude?



As cosine of latitude 42° 11′ ($3\frac{3}{4}$ points),	9·86982
Is to radius, -	10·00000
So is distance sailed, 120, -	2·07918
	12·07918
	9·86982
To difference of longitude, 162	= 2·20936

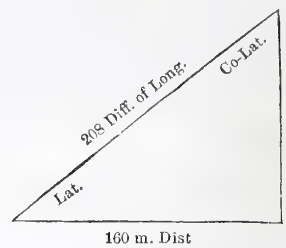
Solution by the Rule.

Set the rod, C, to 42° 11′ ($3\frac{3}{4}$ points), the latitude on the quadrant, A; move the rod, F, to cut 120 (distance sailed) on B; and 162 (difference of longitude) will be given on C.

Given the Difference of Longitude and Distance between two places in the same Parallel of Latitude, to find the Latitude of that Parallel.

Example.—Suppose a ship has sailed directly west 160 miles, and it is found, by observation, that she has differed her longitude 3° 28′, or 208 miles.—What parallel of latitude has she sailed upon?

As difference of longitude 208,	2·31806
Is to the distance sailed, 160, -	2·20412
So is radius, -	10·00000
	12·20412
	2·31806
To cosine of latitude 39° 43′,	= 9·88606
Nearly $3\frac{1}{2}$ points.	



Solution by the Rule.

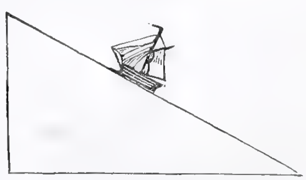
Set the rod, F, to 160 on B; then move C till F cuts 208 on it; and 39° 43′, the latitude, will be given on the quadrant, A.

MIDDLE LATITUDE SAILING.

A ship sailing north or south makes no change in her longitude, the distance run makes her difference of latitude; so that her place is easily known by the latitude left, and difference of latitude. If she sails east or west, there is no difference in latitude, because she sails upon a parallel of latitude, and her difference of longitude is found by parallel sailing; but when she sails upon any other course, she changes both her latitude and longitude.

Middle Latitude Sailing is a combination of plane and parallel sailing, and is an easy mode of solving problems, when the course is neither upon a meridian nor a parallel; although, in many questions not strictly correct, the difference of longitude is reckoned upon the middle parallel between the latitude sailed from and come to.

The middle latitude is half the sum of the two latitudes when added, if they are of the same name; but half their difference if of contrary names.


Plane or Parallel.


Middle Latitude Sailing.

The Latitudes and Longitudes of two places given, to find the Course and Distance between them.

Example.—A ship sailed from latitude 32° 40′ N., and longitude 9° 12′ W., to latitude 29° 12′ N., and longitude 12° 12′ W.—What was her direct course and distance?

Latitude left, - -	32° 40′ N.	Longitude left, -	9° 12′ W.
Latitude in - -	29° 12′ N.	Longitude in -	12° 12′ W.
Difference of latitude,	3° 28′	Diff. of longitude,	3° 0′
	60		60
In miles, - -	208	In miles, - -	180

Latitude left, - - - - -	32° 40′ N.
Latitude in - - - - -	29° 12′ N.
Sum, - - - - - -	2)61° 52′
	30° 56′ Middle latitude.

To find the Departure.

As radius, - - - - - -	10·00000
Is to cosine of Middle latitude, $2\frac{3}{4}$ points, -	9·93335
So is difference of longitude 180, - -	2·25527
	12·18862
	10·00000
To departure, 154, - - - - -	= 2·18862

To find the Course.

As the difference of latitude 208, - -	2·31806
Is to departure, 154, - - - - - - -	2·18862
So is radius, - - - - - - -	10·00000
	12·18862
	2·31806
To tangent of course, $3\frac{1}{4}$ points, 36° 33′, -	9·87056

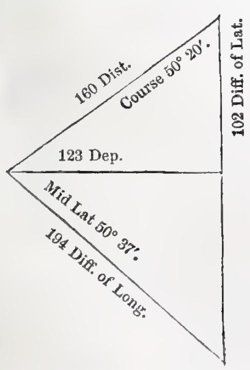
To find the Distance.

As radius, - - - - - - -	10·00000
Is to secant of course, $3\frac{1}{4}$ points, - - -	10·09517
So is difference of latitude 208, - - -	2·31806
	12·41323
	10·00000
To the distance, 259, - - - -	= 2·41323

Solution by the Rule.

For the Departure.

Set the rod, C, to $2\frac{3}{4}$ points on the quadrant, A, as middle latitude; move F to cut 180, difference of longitude, on C, and 154 will be given on B, as the departure. For the course and distance, make F cut 208 on B, as difference of latitude, move C till it cuts 154 on F, as departure, and $3\frac{1}{4}$ points will be given on the quadrant, A, for the course, and 259 will be given on C, as distance.



Given one Latitude, Course and Distance, to find the Difference of Latitude and Longitude.

Example. — Suppose a ship sailed from latitude 51° 28′ N., and longitude 30° 25′ W., 160 miles between south and west, upon a course of 50° 20′.— What is her present latitude and longitude?

To find Difference of Latitude.

As radius, - - - - - - -	10·00000
Is to cosine of course, $4\frac{1}{2}$ points, nearly, -	9·80504
So is the distance, 160, - - - -	2·20412
	12·00916
	10·00000
To difference of latitude 102, - -	= 2·00916

Difference of latitude $\frac{102}{60}$, - -	= 1° 42′ S.
Latitude left, - - - - - -	51° 28′ N.
Latitude in - - - - - -	49° 46′ N.
Sum, - - - - - -	2)101° 14′
Middle latitude, - - - - -	50° 37′ ($4\frac{1}{2}$ points.)

To find the Departure.

As radius, - - - - - - -	10·00000
Is to sine of course, $4\frac{1}{2}$ points, - - -	9·88636
So is distance, 160, - - - - -	2·20412
	12·09048
	10·00000
To departure, 123, - - - - -	= 2·09048

To find Difference of Longitude.

As cosine of middle latitude, $4\frac{1}{2}$ points, - -	9·80244
Is to radius, - - - - - - -	10·00000
So is departure, 123, - - - - - -	2·09048
	12·09048
	9·80244
To difference of longitude 194, - -	= 2·28804

To find the Longitude come to.

Longitude left, - - - - -	30° 25′ W.
Difference of longitude $\frac{194}{60}$, - -	3° 14′ W. add
Longitude come to, - - - - -	33° 39′ W.

Solution by the Rule.

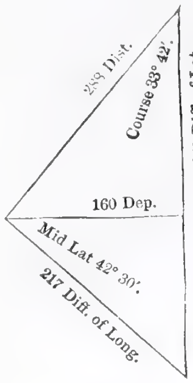
To find the Difference of Latitude and Departure.

Set the rod, C, to 50° 20′, the course; on the quadrant, A, move F to cut 160 on C, the distance; and 102 will be given on B, as the difference of latitude, and 123 will be given on F, as the departure.

For the Difference of Longitude.

Set the rod, C, to 50° 37′ ($4\frac{1}{2}$ points) on quadrant, A; make F cut 123, the departure on B, and 194 will be given on C, for the difference of longitude.

Both Latitudes and Departure given, to find the Course, Distance, and Difference of Longitude.



Example.—Suppose a ship sails from latitude 44° 30′ N., and longitude 8° 6′ W., between south and west, until she arrives in latitude 40° 30′ N., and finds she has made 160 miles of departure.—What is the course she has steered, the distance run, and the longitude come to?

Latitude left, - - -	44° 30′ N.
Latitude come to, -	40° 30′ N.
Difference of latitude,	4° 0′
	60
In miles, - - -	240

Latitude left, - - - - - -	44° 30′ N.
Latitude come to, - - - - - -	40° 30′ N.
Sum, - - - - - -	2) 85° 0′
Middle latitude, - - - - -	42° 30′

To find the Course.

As difference of latitude 240, - - -	2·38021
Is to departure, 160, - - - - -	2·20412
So is radius, - - - - - - -	10·00000
	12·20412
	2·38021
To tangent of course, 33° 42′, 3 points, -	= 9·82391

To find the Distance.

As sine of course, 3 points, - - - -	9·74417
Is to radius, - - - - - - -	10·00000
So is departure, 160, - - - - -	2·20412
	12·20412
	9·74417
To the distance, 288·3, - - -	= 2·45995

To find the Difference of Longitude.

As cosine of middle latitude, 42° 30′ ($3\frac{3}{4}$ points),	9·86763
Is to radius, - - - - - - -	10·00000
So is departure, 160, - - - - -	2·20412
	12·20412
	9·86763
To difference of longitude 217, - - -	2·33649

To find the Longitude come to.

Longitude left, - - - - - -	8° 6′ W.
Difference of longitude $\frac{217}{60}$, -	= 3° 37′ W.
Longitude come to, - - - - -	11° 43′ W.

Solution by the Rule.

For the Course and Distance.

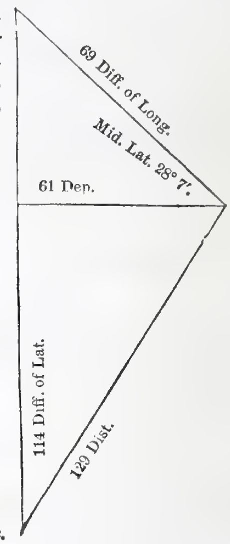
Set the rod, F, to 240, difference of latitude on B; move C till it cuts 160 on F, the departure; and on C will be given 288, for the distance, and on the quadrant will be given 33° 42′, 3 points, for the course.

For the Difference of Longitude.

Set the rod, C, to middle latitude 42° 30′ ($3\frac{3}{4}$ points), on the quadrant A; move the rod, F, to cut 160 on B, the departure, and on C will be given 217, for the difference of longitude.

Both Latitudes and Course given, to find the Departure, Distance, and Difference of Longitude.

Example.—A ship sailed from latitude 27° 10′ N., and longitude 12° 20′ W., NNE. $\frac{1}{2}$E., and finds she is in latitude 29° 4′ N. —What is the distance sailed, and longitude come to?



Latitude left, - - -	27° 10′ N.
Latitude come to, - -	29° 4′ N.
Difference of latitude, -	1° 54′
	60
In miles, - - - -	114

Latitude left, - - -	27° 10′ N.
Latitude come to, - -	29° 4′ N.
Sum, - - - -	2) 56° 14′
Middle latitude, - -	28° 7′

To find the Departure.

As radius, - - - - - - - -	10·00000
Is to tangent of course, $2\frac{1}{2}$ points, - - -	9·72780
So is difference of latitude 114, - - -	2·05690
	11·78470
	10·00000
To departure, 61, - - - - -	= 1·78470

To find the Distance.

As cosine of course, $2\frac{1}{2}$ points, - - -	9·94546
Is to radius, - - - - - - -	10·00000
So is difference of latitude 114, - - -	2·05690
	12·05690
	9·94546
To the distance, 129, - - - - -	2·11144

To find the Difference of Longitude.

As cosine of middle latitude 28° 7′ ($2\frac{1}{2}$ points),	9·94546
Is to radius, - - - - - - -	10·00000
So is departure, 61, - - - - -	1·78470
	11·78470
	9·94546
To difference of longitude 69·7, - - -	1·83924

To find the Longitude in.

Longitude left, - - - - - -	12° 20′ W.
Difference of longitude $\frac{69}{60}$, - - - - -	1° 9′ E.
Longitude in, - - - - - - -	11° 11′ W.

Solution by the Rule.

For Distance and Departure.

Set the rod, C, to $2\frac{1}{2}$ points, the course on quadrant, A; move F to cut 114, difference of latitude on B; and 61 will be given on F, as departure, and 129 will be given on C, as the distance.

For Difference of Longitude.

Set the rod, C, to $2\frac{1}{2}$ points, middle latitude, on the quadrant, A; make F cut 61, the departure, on B, and 69 will be given on C, as difference of longitude.

EARLY HISTORY OF GUN COTTON.

Ten years ago, the newspapers teemed with the marvellous performances of this compound, which one-half the world appeared to have been employed in manufacturing. The history of the invention reminds us of Columbus's egg. Before the details of the process were presented to the public, this inconsistent body pondered in silent admiration upon the wonder-working feat, and was fain to place it in the list of the fairy marvels of bygone days. No sooner, however, was the scheme explained, than the wonder gave way to an exclamation—how simple! and forthwith every one set to work to make it, caring little for bestowing credit on its originator, Professor Schönbein.

Before the Professor's process appeared, Dr. Otto, Professor of Chemistry in Brunswick, published the following statement in the *Hanoverian Gazette*:—

"Entirely independent of Schönbein and Bœttger, but relying on an observation of Pelouze, contained in the 136th page of the first volume of my *Manual on Chemistry*, I have succeeded in producing an exploding cotton, which, after a series of experiments, seems quite suited to supply the place of gunpowder. In order to bring the results of important discoveries as speedily as possible to the highest state of perfection, it seems necessary to lay them before the public, in order that many persons may turn their attention to the subject. I scorn, therefore, to sell or take out a patent for my very interesting discovery, the consequences of which are not foreseen; and I now publish it for the general good of the public. In the preparation of the exploding cotton, common well-cleaned cotton is dipped for about half a minute in highly concentrated nitric acid (the acid which I use being made by the distillation of ten parts of dried saltpetre and six of oil of vitriol), and then instantly placed in water, which must be often removed, in order to free the cotton from the acid with which it is impregnated. Care must then be taken that all the knotty particles of the cotton are properly disentangled, and that it is thoroughly dried. After this, the explosive preparation is ready for use; its effects create astonishment in all who witness them, and the smallest portion explodes, when struck on an anvil with a hammer, like fulminating powder; when kindled with a glowing body, it takes fire just like gunpowder; and when used in a gun, its operation, though in a far greater proportion to its weight, is precisely the same as that of gunpowder. This gun cotton is employed exactly the same way as gunpowder; a piece of it is rammed down the barrel, then a bit of wadding, and after that a ball; a copper cap ignites and explodes the cotton. Without a single exception, all who have witnessed my experiments have been most completely satisfied, but no one has mentioned the matter."

Mr. Thomas Taylor of London, who undertook a series of experiments after Dr. Otto's receipt, gave his own method as follows:—

"Mix in any convenient glass vessel $1\frac{1}{2}$ ounce, by measure, of nitric acid (sp. gr. 1·45 to 1·50) with an equal quantity of sulphuric acid (sp. gr. 1·80). When the mixture has cooled, place 100 grs. of fine cotton wool in a Wedgewood mortar, place the acid over it, and with a glass rod imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely saturated, pour off the acid, and with the aid of a pestle quickly squeeze out as much of the acid from the cotton as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water, or underneath a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water-bath. By employing a large relative proportion of the acids to the cotton, or by using stronger nitric acid, a still more highly explosive compound may be produced; but acid of the strength and in the proportions I have given, affords a very useful article at a moderate cost. Nitric acid of the sp. gr. 1·50 answers much better than that of 1·45, it being a curious fact that the texture of the cotton is much less acted upon by the stronger acid. If the nitric acid has only the sp. gr. of 1·36, the cotton is often converted into a gelatinous mass, and I have no doubt that in the majority of cases, where persons have failed in repeating my process, the failure is owing to their nitric acid being too weak. By the ordinary acid of commerce, I meant that of the *London Pharmacopœia*, which should be of the sp. gr. 1·50, but is seldom more than 1·45. When the very best cotton is required, it will be found advantageous to remove all adhering grease, by first washing the cotton in a weak alkaline solution, and thoroughly drying it before it is immersed in the acid. Being unwilling to detract in any way from the value of any other person's process without sufficient trial, I stated, in my first communication, that my process could only be regarded as a modification of that of Dr. Otto's; it is, however, something more, for I have carefully repeated Dr. Otto's process, using acid of the sp. gr. 1·512; and I may now venture to assert, that although a powerful explosive cotton is produced, it is much inferior in strength to that made with the addition of sulphuric acid. The practical difficulties, moreover, which would be encountered in manufacturing it by his process would be almost insurmountable; and if acid of a still greater were employed, the expenses would prevent its ever being more than an object of scientific curiosity."

With 20 grains of the cotton thus prepared, Dr. Taylor projected a bullet through a deal board an inch thick at a distance of 70 feet, with an ordinary gun. With regard to its fulminating powers, he always found that, when struck with a hammer, only that portion was exploded which was immediately in contact with the metallic surface. With regard to its cost, with reference to gunpowder, a correspondent of the *Mining Journal* wrote:—

"The great sensation that has been caused by the extraordinary results which have emanated from the experiments in gun cotton, and the alleged probability of its superseding gunpowder in mining operations, has led me to make a few experiments and calculations, which are as follow:—The possibility of saturating cotton with nitric and sulphuric acid in certain proportions, and to produce a most combustible compound, is indubitable, and I have succeeded in producing the anticipated results; but the practicable economy must also be considered. The price of gunpowder, over the whole of England, ranges at 40s. per barrel of 100 lbs., or $4\frac{3}{4}$d. per lb. The lowest price cotton, in the Liverpool price currents, is Surat—the price of which is $6\frac{1}{2}$d. per lb. Cost of manufacturing, I calculate—

Nitric acid, at.................................. 1s. per lb.
Sulphuric ditto. ....2d. "

Cotton takes up and holds, when saturated, after pressure, its own weight of water; therefore, 1 lb. of cotton will hold—

1·0000 nitric acid.
·6158 sulphuric acid.

1·6158=1s. $1\frac{1}{4}$d.
0 $6\frac{1}{2}$ cotton.
0 $6\frac{1}{4}$—say, nearly 30 per cent. in labour, loss, and charges.

2s. 2d. per lb. for gun cotton.

"The estimated effect is said to be twice that by weight of gunpowder—say, therefore, 1s. 1d. to do the work of powder. How can, therefore, gun cotton compete with powder at $4\frac{3}{4}$d. per lb.? Again, $\frac{1}{4}$ lb. occupies about 8 cubic inches in bulk; and 2 oz. of cotton, considerably compressed, 27 cubic inches.

of drying it. I offer these remarks to you, as the mining interest seems greatly interested; and I fear they will meet with great disappointment, if they calculate upon the results so bruited about."

After reading this statement, and comparing it with the following experiments made by Mr. Taylor and Professor Schönbein in Wales, as detailed by the former gentleman at the annual meeting of the Royal Geological Society of Cornwall, we could scarcely help feeling some misgivings that the writer was interested in the manufacture of gunpowder:—

"The first experiment was made in a granite quarry near Penryn, at Spargo; and he and Professor Schönbein were accompanied on that occasion by Messrs R. W. Fox, C. Fox, Mr Hoskin (the owner of the quarry), and several other gentlemen. The surprise and incredulity of the workmen were very great, and highly amusing. When he charged a hole with some of the cotton, they thought he was doing a very absurd thing, and one of the men offered to sit on the hole for a pint of beer; but he advised him to see the result of the first explosion before he tried that experiment. They then had two holes prepared; the quarrymen weighed out the quantity of powder required to charge their hole, and he weighed out one quarter of that weight of the cotton. Their charge (said Mr Taylor) was fired, and produced its effect completely; our charge was fired, and to their great amazement, tore the rock to fragments—in fact, doing more than was required, the charge being too great. They had next two strong holes bored in a very compact part of the rock. It required 13½ oz. of powder, and we charged the corresponding hole with 3 oz. of the cotton; their charge was fired first, and did its work well,—and the cotton being fired, did its work well also, the men saying that it could not have been done better. In another experiment, with a smaller quantity, he found that one-sixth part of the cotton did its work; but he did not place much reliance upon that result, as possibly the men might have over-rated their charge. They tried some other experiments with the use of sand and wedges, and he might say that the whole of the experiments were uniformly successful when the charge of cotton was equal to one-fourth the requisite weight of powder. So far the strength of the cotton was demonstrated, but he was then anxious to make experiments in regard to its effects on the air of the mine; and the iron mine of Restormel was selected, on account of its being easy of access, so that the Professor might accompany him without fatigue. From its being in hard ground, and having the adit level driven a considerable distance into the hill, the end of that level was very close, and presented great difficulty in the escape of the smoke of gunpowder. They first tried an experiment in the extreme end of the adit level, six or seven hundred fathoms from the entrance. The miners prepared two holes, but they did not use gunpowder on this occasion, as it would have interfered with their experiments. They asked the men to produce the quantity of powder required for those holes, and then weighed first one quarter and then one-sixth part of the weight of cotton; they fired the two holes, which tore their ground, and the miners said it was quite satisfactory. They told him that, if powder had been used, they could not have gone into the place for three quarters of an hour; but (said Mr Taylor) we went in instantly, the two captains, Professor Schonbein, and myself. We experienced no inconvenience whatever, except from the safety fuse, and that was no inconvenience to them. One quality of the cotton was of great importance to miners; it was not so easily affected by the damp as powder. It was not permanently injured by being wetted, but might be washed and dried, and its explosive power be the same as before: it has been kept in water six months without injury. It might be kept in magazines and tanks in perfect security; and it was an important fact, that there was no danger in the progress of its manufacture,—for, until the process was completed, it was not explosive in any way; and no part of the process involved any danger. He had no sort of knowledge of what the composition was, except that it was a wool basis. With regard to expense, he was assured that a given quantity of power could not be obtained probably for less; but weight for weight it would be more expensive than gunpowder."

About the time that these observations were made, we had the pleasure of assisting at two several sets of experiments with the new explosive compounds, gun cotton, tow, and saw-dust.

The first of these trials was undertaken at the Ladywell Quarry, near Glasgow, the object being to determine how far the new preparation was applicable to blasting purposes. The extreme hardness and solidity of the material upon which the power of the explosion was tested (being whinstone), proved a real *experimentum crucis*, and left no doubt on the minds of the beholders as to its sufficiency in this respect.

A 3½ inch bore, 9 feet in depth, was made in the perpendicular face of the rock; this was charged with 1½ lbs. of gun tow, the whole operation being conducted precisely as observed with gunpowder. In this explosion, our most sanguine expectations were perfectly realized, and we had the pleasure of seeing the front of the cliff heaved up and split in the most complete manner. Scarcely any report was heard, nor was any smoke seen to proceed from the rock, save what was occasioned by the burning of the fuse. As a proof of the correctness of the proportion of tow used in this bore, it is to be remarked that the rock was in no degree shattered, the whole mass being merely raised up in a slight degree, no fragments being projected further than a few feet from the spot.

The different individual peculiarities displayed by numbers of the witnesses pending the burning of the fuse, was not the least curious portion of this investigation—some with a plainly forced easiness of countenance, looked on with a would-be sceptical smile, as if the idea of inserting so harmless a substance as cotton in a rock, was an excessively ludicrous proceeding; others again, who knew practically, or who had more faith in its powers, awaited the result with considerable eagerness, calculating, in their mind's eye, the weight of the adamantine material to be brought down. Upon a subsequent examination of the blast, it was found that about 200 tons of rock was loosened sufficiently to allow of its easy removal with the crowbar, several immense blocks being torn completely off the mass and thrown slightly forward. The quarrymen's charge of ordinary gunpowder, for a similar bore, is 20 lbs.; 20 to 1½ was fearful odds in favour of the new material, and seemed to show that the latter would speedily supersede its ancient substitute for such purposes. Another experiment was afterwards carried into effect with cotton in a 2½ inch bore, 4 feet 6 in. in length, the result being alike successful. The third material, sawdust, was then put in requisition, performing its office in a very satisfactory manner, not, however, producing so great an effect as either of the former substances.

A second trial was instituted a few days subsequent to the one above detailed, the material operated upon being coal. This set of experiments was tried in the Victoria coal-pit at Pollokshaws, near Glasgow, in the presence of Mr. Coates the proprietor. This pit, we may observe, is the deepest in Scotland, the bottom being 180 fathoms below the natural surface of the earth.

An inch bore, 2 feet in length, was made in the breast of the coal stratum, and charged with 1 oz. of cotton; the result was highly satisfactory, a considerable mass of coal being dislodged, with a far less degree of splintering than when gunpowder is used.

Here we had an excellent opportunity of judging as to the quantity of smoke produced by the ignition of the cotton. Upon approaching the scene of the blast immediately after the explosion, we perceived a slight quantity of smoke, which proceeded entirely from the burning of the fuse. Had the blast been effected by the agency of a galvanic battery, we are persuaded that no smoke whatever would have resulted. In a second blast with the same charge the coal was upheaved, but not dislodged; this we surmised might be owing to the porous nature of the material in which the bore was made; the tamping was not dislodged; therefore, the only way in which we could account for the non-removal of the coal was the supposed existence of crevices behind the mass, which permitted the force of the explosion to expend itself against the atmosphere.

To miners, who owe so much to the purity of the atmosphere in which they work, for their safety, the introduction of the cotton, we have no doubt, might prove a decided benefit, as when the immense production of smoke by the explosion of common gunpowder is considered, and further, that this product has in some situations to pass through the whole of the workings, it is evident that the cotton cannot vitiate the atmosphere to anything near the same extent. An analysis of the products of combustion of the cotton gives—

In my experiments I find, at a temperature of 130°, the gun cotton explodes spontaneously—this I discovered in the process

1 equivalent	Xyloïdine or gun cotton,	$C_{15} H_{12} NO_{16}$
26 do.	Atmospheric air (oxygen),	O_{62}
		$C_{15} H_{12} NO_{42}$

Products of Combustion.

15 equivalents	Carbonic acid,	$C_{15} O_{30}$
12 do.	Aqueous vapour,	$H_{12} O_{12}$
1 do.	Nitrogen,	N
		$C_{15} H_{12} NO_{42}$

showing that no evil effect can possibly be occasioned by it. The use of powder as a fuse for blasting purposes might, we should say, be dispensed with, by substituting a thread of the prepared cotton; but as this expedient is attended with some disadvantages in its manipulation, probably the galvanic battery might be the best agent for ignition.

Subsequent to these experiments, we find the following record in a work which was published in 1847:—

"The specification of Professor Schönbein at last announces the mode of preparing the gun cotton patented by that gentleman. We find it is, with a very slight discrepancy, identical with the process with which all the little boys of the three kingdoms have lately rendered themselves familiar. The nitric acid is of a specific gravity of 1·45 to 1·50, and the sulphuric is 1·83. The proportions are one measure of nitric to three of sulphuric acid. The heat generated by the mixture is permitted to pass off, previous to the immersion of the cotton, the proper temperature being about 50° or 60° Fahrenheit. After immersion, the cotton is squeezed by a glass rod to free it from the superfluous acid, and is then permitted to stand for an hour in a covered vessel, previous to the washing process, which is continued until no trace of the acid is detected by the test of litmus paper. Any uncombined portion of the acid is removed by dipping the cotton in a weak solution of carbonate of potash, composed of one ounce of carbonate of potash to one gallon of water. Its explosive force may be further increased by dipping in a weak solution of nitrate of potash, being finally dried in a room heated to 150° Fahrenheit.

"The application of the carbonate and nitrate of potash is not essentially necessary, but the patentee considers that a considerable improvement results from their use. According to his experiments, he finds that three parts by weight produce an explosive effect equivalent to eight parts of the Tower gunpowder. He also says, as indeed Pelouze informed us years ago, that nitric acid alone will answer, but not nearly so well, nor is it so economical as the mixture of the two acids. A new way by which it may be rendered applicable to fowling-pieces, &c., is also mentioned. It consists in moulding or pressing the cotton, when in a wet state, to the form of the piece in which it is to be used, so that, when dry, it retains its figure, and is much more manageable in loading, &c. The patentee's claim is for 'the manufacture of explosive compounds from matters of vegetable origin, by means of nitric acid, or nitric and sulphuric acids.' Our scientific readers will perceive that this claim is a little of the broadest, and generalizes the matter so much as to endanger its validity in point of law. Besides, with the records of the labours of Pelouze before us, we are not inclined to grant the Professor all the credit of it as a scientific discovery. Our readers may judge of the subject for themselves, from the following translation of an extract from the 'Manuel du Cours, de Chemie Organique appliqué aux arts Industrielle et Agricoles,' published some years ago:—

"'In conclusion, we ought to cite the action of azotic (nitric) acid upon cellulose, and M. Pelouze's discovery on the subject. When we digest a piece of rag or a piece of paper in a dilute solution of nitric acid, after a certain time we drive off the water by a slow evaporation, the nitric acid is incorporated with the woody fibre, (la substance ligneuse) and to which it yields its oxygen, abandoning the azotic. The compound resulting from this experiment is cellulose highly oxygenated, which takes fire spontaneously, like a fulminating powder, when put in contact with a substance heated to between 150 and 200 (300 and 400 Fahrenheit).'"

Professor Schönbein, however, claimed the merit of originality in a paper which he communicated, about the same time, to a foreign scientific publication, giving a detailed history of the alleged discovery. He stated that the result of his researches relating to ozône, induced him to turn his particular attention, for the two preceding years, upon the degrees of oxidation of nitrogen, and principally upon nitric acid. His numerous experiments in pursuing his investigations, as related in other scientific publications, led him to adopt a peculiar hypothesis with reference to the so-called hydrates of nitric acid, sulphuric acid, &c., as well as the pure salts of these acids. For a long time he had his doubts as to the existence of such bodies in perfect purity, and he had for some time entertained the idea that the introduction of these imaginary combinations had, instead of having furthered theoretical chemistry, really shackled its operations. Every one knows that what chiefly induced the assumption of these combinations, was the opinion generally entertained amongst chemists as to the nature of nitric acid. Setting out with the notion of the existence of the combination of oxygen with nitrogen, NO_5, as a demonstrated fact, in spite of the impossibility of actually obtaining it, they then assumed that nitric acid proved the existence of certain other combinations which have never yet been obtained. In his opinion, however, there is no degree of oxidation of nitrogen which can be represented by NO_5, and that which chemists designate by the formula $NO_5 + HO$, ought really to be considered as $NO_4 + HO_2$, and he is disposed to view the nitrates $NO_5 + RO$ as being expressed by the formula $NO_4 + RO_2$. Amongst other reasons which led to that opinion, he mentions the fact, that hydrated nitric acid may be formed by the direct mixture of NO_4 with HO_2 or RO_2. Again, as the reason which induced him to regard hydrated sulphuric acid as being properly expressed by $SO_2 + HO_2$, and not by $SO_5 + HO$, and that the sulphate is represented by $SO_2 + HO$, he deems it sufficient to say that SO_2 united to HO_2, occasions what we term hydrated sulphuric acid, and that SO_2 united to BaO_2 or PbO_2, occasions what we called sulphate of oxide of barium or lead. The combination which Rose expressed by $2SO_3 + NO_2$, ought to be in his view $2SO_2 + NO_4$. If this be so, then he regards it as probable that the union of $2 (SO_2 + HO_2) = 2 (SO_3 + HO)$ with $NO + HO_2 (= NO_5 + HO)$ results in $2SO_2 + NO_4$, and that at the same time $3HO_2$ is disengaged, or forms a more intimate union with that which we call the bisulphate of the deutoxide of nitrogen. In other words, he conjectured that the combination of the hydrates of nitric and sulphuric acid would possess an extraordinary amount of oxygen, and form a kind of aqua regia, in which HO_2 would play the part of chlorine. In this hypothesis, and if the HO_2 were removed from this acid mixture by means of an easily oxidizable body, there would remain Rose's combination.

Guided by these considerations, which he perceived were quite contrary to the received ideas of chemists, he began, in December, 1845, a series of experiments, with the aim of testing his hypothesis, and he affirmed that the results he arrived at supported his views. He mixed together flower of sulphur and a certain quantity of the combined acid; and immediately, even at a temperature of 0°, there was a rapid disengagement of sulphurous acid gas without the production of deutoxyde of nitrogen. When the action had ceased, during which there was a development of caloric, there remained a colourless liquid, which, when combined with water, gave off a considerable quantity of deutoxide of nitrogen, and had all the appearances of a solution of Rose's combination in hydrated sulphuric acid. A mixture of four ounces of hydrated sulphuric acid, with a single drop of nitric acid and a little flower of sulphur, evolves a sensible quantity of sulphurous acid, as may be ascertained by holding over the liquid a slip of paper which has been treated with the iodine of potassium, and slightly tinged blue by the action of chlorine. The sulphurous acid, in flying off, will cause the blue tinge to disappear rapidly.

Selenium and phosphorus are also oxidized at low temperatures in the combined acid, and the latter, at a certain point, abundantly disengages the gaseous deutoxide of nitrogen on the addition of water. Iodine, when powdered and agitated in the combined acid, readily absorbs oxygen if exposed to a low

temperature, and then it forms iodic acid, as well as other combinations. When the chemical action is over, there remains a liquid which, diluted with water, throws off an abundance of gaseous deutoxide of nitrogen, and iodine is precipitated.

His experiments with ozône showed him that this body, which he considers as a peroxide of hydrogen, forms, as well as chlorine, at the ordinary temperature a peculiar combination with olefiant gas, without apparently causing the slightest oxidation of the hydrogen any more than the carbon of the gas, and he conceived the idea that it would be possible that certain organic matters, exposed to a low temperature, should also form combinations either with the peroxide of hydrogen alone, which in his hypothesis is found in a state of combination, or mixture, in the combined acid, or with NO_4. It was this conjecture that principally led him to undertake his experiments with sugar. He formed a mixture of one part (volume) of nitric acid of 1·5 specific gravity, and two parts of sulphuric acid of 1·85 specific gravity, at a temperature of 2°, and then added finely-powdered sugar, so as to make the whole of the consistence of soup. He stirred up the compound, and at the end of a few minutes the sugar was again united in a viscous mass, entirely distinct from the liquid acid, without any development of gas. This pasty mass was washed with boiling water until the acid was completely taken out of it, and then he dissipated, as well as he could, the aqueous particles by means of the application of gentle heat. The substance thus obtained possessed the following properties:—Exposed to a low temperature, it was compact and brittle; at a gentle temperature, it could be kneaded like jalap resin, and a silky brilliancy is given to it; at the temperature of boiling water, it is half liquid, and upon a stronger application of heat, red vapours were evolved; heated still higher, it suddenly took fire, and went off without leaving any residuum. It was nearly tasteless and colourless, transparent like resin; nearly insoluble in water, but easily dissolved in essential oils, ether, and concentrated nitric acid; and in the majority of cases in which he tried it, it had the chemical and physical qualities of resins. Friction rendered it negatively electric. The acid mixture, by means of which this body was obtained, possesses a singularly bitter taste.

Schönbein then went on to experiment with other bodies in December, 1845, and the two succeeding months. In March, he sent specimens of the substances he had procured to some of his friends, particularly to Dr. Faraday, Sir John Herschel, and Mr. Grove, and he expressly states that gun cotton formed part of these substances. About the middle of April, he was invited to Wurtemberg, where he made many experiments with the gun cotton; some in the Ludwigsburg arsenal, in presence of the artillery officers, and some at Stuttgard, before the king himself. In the course of May, June, and July, he repeated his experiments at Basle, before several military men, with all kinds of fire-arms, and after assuring himself that the substance in question would suit arms of large bore, he fired the first cannon charged with gun cotton, on the 28th July. A little before that period he had applied the gun cotton to the blasting of rocks at Istem, in the grand duchy of Baden, and in blowing up the old walls at Basle. In both instances, he asserts, the superiority of the new substance over powder was incontestable.

Experiments of this kind, which had been made in the presence of a great number of persons, could not remain a secret, and the public prints on the Continent were not slow to give accounts more or less exact of the results he had obtained, but without his concurrence. This circumstance, joined to a slight notice which he had himself published in Poggendorff's Annalen, did not fail to attract the attention of the German chemists, and about the middle of August he received from Professor Boettger of Frankfort, the news that he had succeeded in preparing explosive matter from cotton and other substances. Thus the two names of Schönbein and Boettger have been frequently associated in the history of this discovery. In the month of August, Schönbein came to England, and, assisted by Mr. Richard Taylor of Falmouth, he made a great many experiments in the mines of Cornwall, which had entire success in the judgment of all who beheld them. Mr. Taylor afterwards made, under the Professor's direction, several experiments in other parts of England, as to the operation of the gun cotton in fire-arms, and the results were in every way satisfactory. Up to this time there had been little or no attention paid to the matter on the part of the French chemists, and it seems that the experiments of Mr. Grove at Southampton, at the meeting of the British Association, first drew the notice of the French to this substance. It was at first deemed an incredible matter amongst the Parisians, and gave rise to some humorous observations; but when there could no longer be any doubt upon that head, and the chemists of other countries had made known their processes of preparing the cotton, then they took a lively interest in the thing all at once, and they pretended to find in the explosive body an old French discovery. It is nothing more, said they, than the xyloidine which Braconnet found out, and which Pelouze experimented with; still they gave Schönbein the merit of putting the substance into the barrel of a musket. An acquaintance with the composition of xyloidine might have convinced the advocates of that opinion, that it was not suitable for fire-arms on account of its containing too much carbon and too little oxygen, so that combustion is requisite to create gaseous matter. It would have been easy otherwise to see that there was an essential difference between xyloidine and gun cotton—nevertheless, the error survived through some months.

In the early part of November, 1846, Mr. Walter Crum, of Glasgow, published a memoir, in which he showed that gun cotton is not the same product as xyloidine, and that they are essentially different compositions; and towards the middle of the same month, the Academy of Paris received a communication to the same effect. Then, as gun cotton was not xyloidine, they termed it pyro-xyloidine, and they admitted that the first-named substance would not do for fire-arms.

"If, then, it is clear," asks Professor Schönbein, "that since the commencement of 1846, I have prepared gun cotton, and that Mr. Boettger has done the same thing since August; if it is admitted that xyloidine cannot perform the purposes of the cotton, and if it is a matter of public notoriety, that what they now call pyro-xyloidine was not brought to the knowledge of the French Academy and the scientific world, until the middle of November, 1846, can it be seriously intended to claim, on behalf of France, the discovery of gun cotton, and to grant me no other merit than that of having first applied to a practical purpose what another had found? I appeal then to the justice of Frenchmen, to decide whether it is to me, or to Braconnet, or to Pelouze, that the honour belongs, not merely of applying this substance in a particular way, but of actually discovering it. I expressly assert, that I was not led to make the discovery by the knowledge of xyloidine, however near be the connection of that substance with gun cotton. It was the theoretical ideas that I have mentioned before, which, whether erroneous or not, guided me to what I have laid before the world. *Suum cuique* is a moral principle on which the whole of society rests—why should it not be strictly respected in the republic of science? M. Pelouze is a distinguished chemist, he already possesses too good a name to need that his pretensions should be founded on another man's, and I am convinced that this estimable philosopher, when he considers the facts with an impartial mind, will voluntarily give me the credit of that to which I am entitled."

The following is the statement which Professors Schönbein and Boettger have published respecting the same substance:—

"In spite of the desire which we feel to refrain for a while to make known the composition of gun cotton, several considerations have determined us to break silence before we wish. One of us has found that the best substance to dissolve and purify woody fibre, and particularly cotton for explosion, is acetic ether. Analysis of 100 parts of cotton, prepared with the greatest care, and dried in a sand-bath at a temperature of 100° C., gives the following result:—

	Analysis.	Theory.
Carbon, . .	27·43	28·1
Hydrogen, .	3·54	3·1
Nitrogen, .	14·26	14·5
Oxygen, .	54·77	54·3

The purest xyloidine is composed, according to Mr. Ballot's analysis, of

	Analysis.	Theory.
Carbon, .	37·29	37·31
Hydrogen, .	4·99	4·84
Nitrogen, .	5·17	5·76
Oxygen, .	52·55	52·09

The slightest attention is sufficient to show that the composition of the cotton differs very considerably from that of xyloidine, and that it constitutes a combination poorer in carbon and richer in oxygen than that of Braconnet; and that, consequently, on being burnt it ought to produce more gas, to have a greater explosive force, and to leave less residuum than xyloidine. In other properties also, the two substances will be found to differ on examination; for example, we know that at a highish temperature xyloidine is dissolved by concentrated vinegar, and that, when water is added, it appears again unaltered, whilst gun cotton is insoluble in that acid. At the heat of boiling water, xyloidine dissolves in hydrochloric acid of 1·12 specific gravity, and in nitric acid of 1·38 specific gravity; the solution is colourless, and water will not precipitate the xyloidine. Gun cotton is quite unaffected by these acids: xyloidine inflames at 180°; gun cotton, exposed in an oil-bath to a temperature of

218°	inflames	instantaneously.
200°	„	in about 12 seconds.
175°	„	in about 30 seconds.
150°	„	in about 12 minutes.
130°	does not inflame at all."	

FARRIERY.

CHAPTER V.

TEETH OF THE HORSE—CONTINUED.

In the upper jaw, the nippers are stronger, broader, and more developed than those of the lower jaw, and this occasions the outer edge of the lower corner teeth to rest against the centre of the upper corners, and rubs them down so much, that, in some jaws, a triangular nick is made, which, in some degree, assists in determining, with tolerable accuracy, the age of a horse. This nick never makes its appearance until the horse is seven years old, and wears off in the course of time, but soonest in those jaws which are most horizontal.

The figures given on Plate VI., will give some idea of the six incisory teeth or nippers, as well as of their internal organization.

Fig. 8 shows the cavity of the funnel of the table in the tooth of a foal, which is seen from the posterior or inner surface.

Fig. 7, another tooth of a foal, shows the body of the tooth, *a*, the neck *b*, and the root, *c*.

Fig. 16, the tooth of a very young foal, in which the outer enamel is cut through its whole length, and showing the central enamel.

In the cranium of the very aged horse, called Old Billy, already mentioned, the molar teeth are worn in a remarkable manner; the first, on the under jaw, on both sides is worn down to half an inch above the gum; the second is on a level with the gums, forming a hiatus, into which the second molar tooth of the upper jaw fits, and which is somewhat more than a quarter of an inch longer than the first grinder, and very uneven and unequal on the surface. The outer portion of the fourth grinder, to the extent of half an inch, is parallel with the third, the remaining part is worn level with the jaw; the fifth and sixth grinders are nearly worn level with the jaw, with the exception of a small part of the sixth. In the upper jaw, the third molar is more than half worn down, while the fourth is worn level with the socket; part of the fifth and sixth are worn obliquely down, the cavity formed by which is occupied by the projection of the lower tooth opposite to it, and the worn down portion of the fifth and sixth of the lower jaw are occupied by the opposite ones of the upper jaw. So remarkable are the elevations and depressions, that it is curious that mastication could be performed.

The following table will form a ready guide for tracing the age of a horse, and briefly comprehends all the points already more fully detailed.

TABLE EXHIBITING THE DENTAL INDICATIONS OF THE AGE OF A HORSE FROM FIVE TO TWENTY-TWO YEARS.

Year.	Nippers.	Dividers.	Corner Teeth.	Observations.
5	Mark more or less lost,............	On a level with the nippers, and the inner on a level with the outer edge,	Lower than the dividers, nick on the inner edge, which is not on a level with the outer,	Teeth quite fresh, the area of the dental region forming a regular semicircle.
6	Mark lost, and of outer blind pouch slightly concave in the middle,	Mark,..................................	On a level with the dividers, outer edge a little worn.	Centre teeth with a slight yellowish tinge.
7	Central enamel triangular,.......	Mark lost, central enamel concave in the middle.	Inner edge on a level with the outer; beginning to lose the marks.	Same mouth with a nick in the upper corner.
8	Oval central enamel rounded, and very near the inner edge.	Oval, central enamel triangular.	Mark lost, central enamel concave in the middle.	Appearance of mouth, and of blind pouch of inner cavity, in the form of a small, yellowish, or greyish band, longest trans versely, and situate between the central enamel and the inner edge of the tooth.
9	Rounded, central enamel round, and very near the inner edge.	Oval, central enamel rounded, and approaching the inner edge.	Oval, central enamel triangular.	
10	Rounded, central enamel round, and still nearer the inner edge.	Rounded, central enamel round, and still nearer the inner edge.	Oval, central enamel round, and still nearer the inner edge.	
11	Rounded, central enamel gone, or only forming a small round speck, close to the inner edge.	Rounded, central enamel as in the nippers.	Rounded, central enamel as in the nippers and dividers.	
12	Rounded, central enamel quite gone,	Rounded, central enamel quite gone.	Rounded, central enamel quite gone.	Yellowish band of greater extent.
13	Rounded, ...	Rounded,..............................	Rounded, ...	Sides of the nippers a little elongated, septum at the root of dividers rounded.
14	Triangular,...........................	Rounded,..............................	Rounded,..............................	Dividers becoming long.
15	Triangular,...........................	Triangular,...........................	Triangular,...........................	Central enamel of upper teeth not quite gone.
16	Triangular,...........................	Triangular,...........................	Triangular,...........................	Corner teeth becoming triangular.
17	Triangular,...........................	Triangular,...........................	Triangular,...........................	Sides of triangle all of equal length.
18	Triangular,...........................	Triangular,...........................	Triangular,...........................	Lateral portions lengthen in proportion.
19	Flattened from side to side,......	Triangular,...........................	Triangular,...........................	Dividers becoming oval.
20	Flattened from side to side......	Flattened from side to side,......	Triangular,...........................	All the nippers converge towards each other.
21	Flattened from side to side,......	Flattened from side to side,......	Flattened from side to side,	
22	Flattened from side to side......	Flattened from side to side,......	Flattened from side to side,......	All teeth an outward inclination.

It is difficult to say to what age the horse usually lives when in a state of unrestrained freedom. But estimating the average of those in a state of servitude, which have not been overworked, it seems probable that the natural period of his life is from thirty-five to forty years. We are informed by Blaine, that one gentleman had three horses which lived to

a considerable age, viz., one to thirty-five, another to thirty-seven, and a third to thirty-nine. Mr. Cally tells us of a horse that was forty or forty-eight years old. Albertus says, in his time there lived a charger which was still serviceable at the age of sixty; and we are told by Augustus Nephus, that there was one in the stable of Ferdinand the First that had attained the age of seventy years, which is the oldest horse on record; so that Old Billy, which survived SEVENTY-SIX years, must be the oldest horse that ever lived in a domestic condition. And this is the more remarkable, as he was hard-worked for many years, at the laborious employment of dragging the boats on the Bridgewater canal at Manchester.

Besides what we have already noticed, various tricks are practised to impose upon the unwary, to produce a youthful appearance in the teeth of the horse. Among these, what is termed *bishoping* is one of the most fraudulent. This is to imitate the mark, after it has become obliterated by age. This is accomplished by means of an engraving tool, by which a hollow is dug into the surface of the corner teeth, so as to imitate that of a horse of six or seven years old; it is then burned by an iron until it produces a brownish-black stain. This is sometimes done also to the dividers. But it is only the uninitiated who are imposed on by this, as the irregular appearance of the cavity, the diffusion of the black stain around the tushes, the sharpened edges, and concave inner surface, cannot be imitated so successfully as to deceive those who are accustomed to examine the mouth of the horse. The examination of the nippers of the upper jaw will at once prove the trick, as they cannot be altered. But besides the teeth, aged horses will always exhibit other signs, to enable persons to form a judgment on their age. The temporal fossa or pits above the eyes become sunk, grey hairs make their appearance about the eyes and the muzzle, the lips become thin and hanging, the back becomes hollow, the withers get sharpened, the quarters lengthened, spavin and windgalls, and tumours of all kinds disappear; the animal becomes dull and heavy, and the head hangs.

CHIEF MUSCLES OF THE LIMBS, ETC. OF THE HORSE.

It is only a knowledge of the external layer of muscles which is more immediately useful to the popular reader, and we therefore confine our observations to those which are on the surface, and which can be understood by those who have not scientifically studied anatomy. By this superficial knowledge of the action of those on the surface, the seat of bruises and sprains will be detected, and relief may, in consequence, be administered when the services of regular farriers cannot easily be obtained.

MUSCLES OF THE OUTSIDE OF THE SHOULDER.
PLATE VII., Fig. 1.

This portion of the horse is called the *inferior cervical region.*

Part of the *sterno-maxillaris, a,* which is situate in the lower part of the neck. It is of an elongated form, cylindrical, and flattened above and below. It is attached posteriorly to the cariniform cartilage of the sternum or breast-bone, and anteriorly to the angle of the lower jaw. (See Plate III., *t, w.*) It is one of the muscles by which the head is lowered. It lies immediately under the skin. It traverses the neck in an upward oblique direction, curving with the neck, and is of moderate size and strength. At about three-fourths of its upward length, it becomes a flat tendon. Above this, it enters between the parotid and submaxillary glands, and finally is inserted into the angle of the lower jaw. Its structure is tendinous and fleshy at the sternal end, and intimately united with its fellow. Its action is to inflex the head towards the breast. If one muscle act alone, it will, during this inflection, incline the head to one side. When both are exerted, they will assist in opening the mouth.

A portion of the *trapezius, b b,* or quadrangular muscle. This muscle is situate upon the side of the withers. Its form is a right-angled triangle, with its base turned upwards, and the right side forwards, in a parallel line with the spine of the scapula. It is attached above to the spinous processes of the third, fourth, and sixth dorsal vertebræ, and to the ligament and bands which invest them, and below to a small tubercle upon the spine of the scapula. Its action is to elevate the scapula, and when the posterior fasciculi prevail, to incline the bone at the same time backwards. It also assists in supporting the shoulder, and is one of the most important muscles connected with the action of the horse, and strongly illustrates the advantage of high withers and a slanting shoulder. We have represented a portion of it turned back, to exhibit the other muscles below it. It will be apparent, therefore, upon reflection, that a certain degree of fullness and fleshiness is requisite about the withers; otherwise, although there may be sufficient height of withers and obliquity of shoulder to give full action, there will not be sufficient muscular power to enable the horse to perform its work either with energy or continuance.

The *serratus magnus, c d,* or great saw-like muscle, which constitutes the larger portion of the lower part of the neck. It is deeply seated, and situate between the shoulder and side of the chest. Its form in outline is semicircular, with the muscular fibres radiating from a centre, and forming an indentated or serrated circumferent border. It is attached anteriorly to the bodies and transverse processes of the fourth, fifth, sixth, and seventh cervical vertebræ, and posteriorly to the eighth anterior ribs, as low down as their cartilages, by as many fleshy digitations outwardly, to the upper and inner part of the scapula or shoulder-blade, occupying the space between the origin of the *subscapularis* and the insertion of the rhomboidæ. The fibres converge from their various circumferent attachments, like the leaves of a fan, to one common focal point, which is its insertion into the scapula. This muscle forms the principal agent of support to the trunk, maintaining it and the shoulder in close apposition. This pair of muscles are more or less concerned in all the motions of the scapula, and will become dilators of the chest whenever they are exerted, while the limbs remain fixed points.

This muscle performs another important function when the horse is in a standing position. The shoulders and limbs are then rendered fixed and immoveable by the weight of the body; consequently, this muscle being rendered incapable of moving the limbs, its power is exerted in enlarging the cavity of the chest, and this materially aids the animal in breathing more freely.

A portion of the *levator humeri, e,* or raiser of the shoulder. This extensive muscle takes its rise at the tubercle of the occiput, at the back of the head, 3 (Plate III., fig. 1); also to the mastoid process of the temporal bone, 4, 4; to the transverse process of the atlas, and those of the second, third, and fourth cervical vertebræ; and, latterly, from the ligament of the neck, and also the fascia covering the side of the neck; and below and behind it is loosely attached to the head of the humerus; to the fascia of the scapula; likewise to the muscles about the point of the shoulder; and, lastly, to the ridge upon the body of the humerus, which arises from its greater tubercle. The jugular vein runs along its front lower border, and is covered by it for three-fourths of its length downwards. Its front lower margin is thin and expanded, and clips inward, forming a thin fleshy partition between the carotid artery and the jugular vein. Its direction is longitudinal, sloping with the neck. Its action is to raise the shoulder and arm, and at the same time draw them forward, or, as these parts being fixed, to turn the neck and head also to one side, or, should both act under such circumstances, the head will be depressed. This is a muscle of great utility and of immense power.

The *pectoralis parvus, f,* or small pectoral muscle. It lies below the greater pectoral muscle. It is attached inwardly to the side of the anterior half of the sternum, or breast-bone, and to the cartilages of the first four ribs; outwardly to the fascia covering the muscles in front of the scapula and shoulder joint, extending nearly as high up as the place of origin of the antea-spinatus. Its structure is fleshy, with the exception of its lower termination, which is aponeurotic. Its fleshy parts are formed into layers, one overlapping another. Its action is to assist the greater pectoral muscle—*pectoralis major.*

The *antea-spinatus* muscle, *g,* occupying the fossa before the

spine. Its form approaches that of an extended triangle, having its base thick and turned downwards, with its apex thin and rounded off. It is attached above to the fossa of the antea-spinata; likewise to the spine and the ribs of the scapula; below to the summits of the greater and lesser tubercles of the humerus, and to the capsular ligament of the shoulder-joint. It is oblique from above downwards, and from behind forward. Its action is to extend the humerus upon the scapula, at least to approach that bone to the straight line. It is a muscle of great strength.

The *postea-spinatus* muscle, *h*. It occupies the *fossa postea-spinata*, behind the spine or ridge. Its form is triangular, flattened, broader, but not so thick as the antea-spinatus. It is attached above to the surface of the fossa postea-spinata, and to the spine of the bone, and below to the outer side of the greater tubercle of the humerus, to a bony ridge extending down from it, and to the capsular ligament of the shoulder-joint. Its superior attachments are aponeurotic as well as fleshy. Its middle exhibits several broad tendinous intersections, from the principal of which emanates a flattened tendon, fixing the muscle to the tubercle. Below the tendon is the tendinous and fleshy portion attached to the ridge, and, still lower, is a distinct and separate fasciculus, proceeding to a small tubercle upon the same ridge. Its action is to assist in the flexion of the humerus, and, at the same time, to roll it inwards.

Three divisions of another muscle, *i, j, k*, concerned in the same office with *l*, arising from the scapula of the lower bone of the shoulder, and likewise attached to the points of the elbow by a very powerful tendon.

The *middle flexor, m*. This is one of the many and powerful muscles which bind the leg. It has its origin from the inner head of the lower bone of the shoulder, and is inserted into one of the bones on the inner side of the knee. The external flexor of the leg, which is the other, is seen at fig. 3. It takes its name from being situate on the outer side of the arm, towards the back. It is inserted on the outer head of the lower bone of the shoulder. As it approaches the knee it is tendinous, and the tendon divides into two portions, one of which is inserted into the same bone of the knee, and the other into the outer small bone of the leg. The *internal flexor* is shown at Plate VII., fig. 4.

One of the muscles of the lower bone of the shoulder, *m*. It is the external one, and its use is to bend the arm, and takes its rise from the inner and back part of the neck and body of the lower bone of the shoulder, turning obliquely round it, and is inserted into the inner and upper portion of the bone of the arm.

The *extensor* of the leg, *n*. It is the principal one for moving the limb, is of considerable size, and is situate in the fore part of the arm. It takes its rise from the lower part of the body of the lower bone of the shoulder, and forms its outer head, descending down the arm and becoming tendinous. The tendon passing under one of the ligaments of the knee spreads out, and is then inserted into the fore and upper portion of the shank-bone. It is also seen at

The *middle flexor, o*, or muscle which bends the shank-bone. It is placed exactly in the middle of the back part of the arm. It takes its rise from the inner termination of the lower bone of the shoulder, and is continued and inserted into one of the bones on the inner side of the knee. It is likewise seen at *x*.

The *external flexor* of the leg, *p*, which is placed on the outer side of the arm, towards the back. It rises in the outer head of the lower bone of the shoulder, and stretches towards the knee. Its substance is tendinous, and divides into two portions, one of which is inserted into the same bone of the knee, and the other into the small bone of the leg.

The *perforated flexor* muscle, *q*, which arises from the lower back part of the inner head of the lower bone of the shoulder, and is intimately intermixed with, or more correctly the origins of the *perforating flexor*, and, descending along the bone of the arm, becomes tendinous, and, as it approaches the knee, it is fastened down by arches or ligamentary bands, to prevent it starting in sudden and violent action. Taking its rise in the knee, it widens and partially wraps round the tendon of the perforating muscle, and they descend together in juxtaposition, but are not adherent, but freely glide over each other, without friction, by the aid of the mucous fluid. They are both enclosed in a sheath of compact cellular substance, which is attached to them by numerous fibrils, and they are also supported by various ligamentous expansions. Near the fetlock, the tendon expands still further, and forms a complete ring around the tendon of the perforating muscle. This will be manifest in Plate VI., fig. 3. The use of this will be pointed out when we are describing the fetlock. Near this the tendon divides, and is inserted into the smaller and longer pastern bones and the flexors which bend them.

The *perforating flexor* muscle is next, and has nearly the same origin as the *perforated flexor*, but is furnished with somewhat distinct heads, and continues muscular further down the limb than the perforated, and lies before it. Like the perforated muscle, at the knee it passes under strong ligamentary arches which bind it in its situation. It then assumes a round form, and is partially wrapped up in the perforated flexor, and at the fetlock is completely surrounded by it. It emerges from the perforated flexor when that tendon divides, and continues its progress alone after the other has become inserted into the pasterns, and, after passing over the navicular bone, terminates on the base of the coffin-bone, or bone of the foot.

The *subcutaneons vein* of the side of the chest, *r*.

MUSCLES ON THE INSIDE OF THE SHOULDER.

PLATE VII., Fig. 2.

One of the most powerful of the flexor muscles is the *flexor of the arm, a*. It takes its rise from the extremity of the ridge of the shoulder-blade, in the form of a large and round tendon, and extends between two prominences in the upper portion of the front of the lower bone of the scapula. This groove or pulley is perfect in its construction, and is lined with smooth cartilage, between which and the tendon there is interposed an oily fluid, by means of which the tendon moves in this pulley, without the danger of being injured by friction. Emanating from this pulley, and extending beyond the head of the lower bone of the shoulder, the cord spreads out into a round muscular substance containing many tendinous fibres. It is deaply seated, and produces that roundness and fulness to the front of the arm. It is inserted into the head and neck of the bone of the arm, and likewise into the capsular ligament of the elbow-joint. This is the principal muscle which gives motion and action to the whole of the leg below the arm, and also bends it.

The *pectoralis transversus* muscle, *b b*. This muscle crosses the breast. It emanates from the first four bones of the chest, passing over the inner portion of the arm, and is inserted into the tendinous substance which covers the muscles of the fore-arm, extending a considerable way down it. Its office is to bend the arm to the side of the horse, and it likewise keeps the legs straight in front of the animal when galloping at its speed, and concentrating the weight of the body on the limbs, in a direction most easy and safe for him as well as the rider, and most advantageous for the full action of all the muscles connected with progression.

Capped hock, *c*, or an enlargement of the elbow-joint.

The internal flexor, *g*, which takes its rise from the inner head of the lower bone of the shoulder, and is inserted into the head of the inner splint-bone. Its office is to bend the leg, and turn it very slightly.

The chief veins, arteries, and nerves of the shoulder and arm, *d*.

CHIEF MUSCLES OF THE OUTSIDE OF THE THIGH.

PLATE VII., Fig. 1.

The *gluteus maximus*, or great glutæus muscle, *a*. This muscle is situate in the anterior, middle, and external parts of the haunch. Its form is pentagonal, with unequal sides; the angles rounded, and with the lowermost angle extended. It is attached above to the spinous and transverse processes of the two or three last lumbar vertebræ, to those of the two

or three uppermost sacral, and to the fascia lumborum; also to the edges of the ilium, its back and hinder spine; lastly, to the sacro-seatic ligaments, and below to the trochanter major. It is related externally with the gluteus externus and the skin, and internally with the dorsum ilei and gluteus internus; before with the tensor vaginæ, and behind with the lumbar and sacral spines, &c. This is a bulky muscle, entirely fleshy, with the exception of some broad tendinous intersections, which, at the trochanter, become formed into a broad flat tendon, surrounded by fleshy fibres.

The *gluteus externus*, or outer glutæus muscle, *b*. It is situate on the mesio-external part of the haunch. Its form is triangular, and is but a fleshy slip attached to the great glutæus muscle. It is attached above to the front superior and inferior spines of the ilium, to the spine of the sacrum, and to the fascia lumborum, and below to the smaller external trochanter. It is constituted of two fleshy divisions, with a broad interval between them, filled by aponeurosis. The front or smaller division is tendinous above, and internally its fibres are interlaced with those of the gluteus maximus. Below, both portions unite into one common triangular fleshy belly, which terminates in an aponeurotic tendon, and from this are sent down processes to the tibial fascia.

The above two large and powerful muscles are extensors, either of the os femoralis upon the pelvis, or of the pelvis and loins upon the hind quarter. When the limb has been moved in advance under the body, by the muscles of the anterior femoral region, and the toe of the animal firmly placed upon the ground, the glutei, by extending the haunch, will carry the trunk forward, thus becoming most powerful agents in progression; and of the two, the maximus is by far the most powerful. Both in rearing and kicking, these muscles are thrown into violent and forcible contraction. In the former action, the limbs become the fixed points; in the latter, the trunk. These muscles almost entirely act in a right or perpendicular line, in which line the greatest mechanical power is gained. If the skeleton of the horse is examined (Plate I.), it will be manifest; and this advantage is the more needful, because, as is almost universally the case, there is a corresponding disadvantage to be overcome. These muscles are inserted into the great trochanter, or that protuberance of the upper bone of the thigh; and that is but slightly removed from the joint or centre of motion. The power being thus close to the centre of motion, the weight supposed to be concentrated in the middle of the limb is far removed. It is about thirty times as far as the power; consequently, this muscle must act with a disadvantage of more than thirty to one. Or, supposing the hinder extremity and the weight of the trunk above amount to 600 pounds, the force applied, or the power of the muscle, must be equal to 30 times 600, or 18,000 pounds. This muscle having numerous origins, and the extensive surface whence they arise, and their very great dimensions, render their power equal to this; and, as is known with regard to the flexor muscles of the arm, what is lost in power is gained by velocity; for while this portion of the upper thigh-bone moves with rapidity through a certain space, by the powerful contraction of the glutæus muscles and other muscles, the extremity of that bone moves through thirty times the space, and the extremity of the entire limb or foot moves through more than one hundred times that space. From this cause, and this alone, comes the great speed of the horse.

Important considerations arise from these structures; for in proportion as this protuberance behind and above the joint is lengthened, so is the shorter arm of the lever, and, consequently, the muscular exertion modified. This protuberance is lengthened in proportion to the length of the croup and the depth of the quarters; therefore, this conformation is of the utmost importance. This character is of equal importance as regards the depth of the elbow. In this part, however, it is of still greater importance; because these are the points on which especially depend the power and speed of the horse. Horses used in hunting and on the turf are always most appreciated when the quarters commence from about the middle of the back, and extend to the back downwards and to the tail behind. No points of the frame of a horse are of so much importance as the quarters; power is indicated by their muscularity, as also the depth and direction of the quarters.

The *glutæus internus* is deeply placed under the above two muscles. Its origin is fan-shaped, with its fibres describing two contrary curves. It is principally of a fleshy structure, the lower portion of which is intersected, at regular distances, by layers of tendon, which at the trochanter become united together into one broad flat tendon, curiously grooved in rays upon its internal surface. This muscle cannot be seen without the other two being removed. It assists in performing the same office as the other two. There are likewise other muscles, emanating from different parts of the haunch, which assist in producing the same action as those above named, two of which require special observation.

The *triceps femoris*, *c*. It takes its rise high up from the bones of the spine, as well as from others at the root of the tail; from the protuberances of the ischium, as well as from the pelvis bones; and occupies the outer portion of the quarter behind, and is very conspicuous in the blood-horse. Although it is usually called one muscle, it is properly speaking three, having this number of heads. It is inserted into the lower bone of the thigh. Its office is to draw back the thigh when placed under the trunk, and in this action it urges forward the body. It is inserted in nearly a perpendicular direction, and, in consequence, is endowed with great power.

Behind the above muscle, there is one, *d*, which likewise descends from the first bones of the tail, and forms the hinder border of the haunch. It is inserted into the lower bone of the thigh, and assists in performing the same kind of motion. In the thorough-bred horse the whole of these muscles are very prominent, and which give him that great strength and speed. To perform their complete action, these muscles ought to be so developed, that when a person stands behind the horse, although of sufficient width at the loins and haunch, they should yet be perceptibly wider at the thighs.

The tendinous expansion, *e*, which binds and strengthens the above muscles.

The *flexor metatarsi*, *f*—bender of the leg—or muscle used in bending the hock. It emanates from the lower part of the upper bone of the thigh, and is inserted into the upper part of the shank-bone, and also the inner splint-bone. This is a very powerful muscle.

The root of the tail with its muscle, *g*.

The *extensor pedis*, *h*, is situated on the fore part of the thigh, and is fixed to a roughened depression upon the lower front portion of the outer condyle of the femoral bone, and below to the coronal process of the *os pedis*, and to the upper margin of the bone in the interval between the lateral cartilages. Its office is to extend the foot, as also the fetlock and pastern joints.

The letter *i* marks the situation occupied by the principal nerves before they pass under the muscle. They follow a course nearly in a line with the letter *l*.

The *femoro-tibialis obliquus*, or *popliteus* muscle, *j k*, which is situate at the back of the stifle-joint. Its form is short, thick, and triangular. It is attached above to the postero-external side of the outer condyle of the femur, and to the capsular ligament of the stifle-joint, and below to the upper half of the inner side of the body of the tibia. Its action is to lead the stifle, and, at the same time, to turn the tibia inwards. It also extricates the capsular ligament from being pinched between the bones.

The use of the muscle marked *l*, is to extend the hock. It has great power, and has its origin in the head of the upper bone of the thigh, and is attached midway down to the lower bone of the thigh, terminating in a flat tendon, which is fixed into the joint of the hock. It is advantageously situate for great exertion, as it acts nearly at right angles.

The *peroneo-prephalangeus*, or *peroneus*, *m n*, is another of the extensor muscles. It is situate on the fore external side of the limb. It is heart-shaped, elongated, and flattened from before backwards. It is attached above to the head of the

fibula, and continuing its attachment the whole length of the bone, becoming tendinous before reaching the hock. Its upper attachment is fleshy and tendinous, from which a fleshy belly descends nearly the whole length of the tibia. It then assumes the form of a tendinous fleshy cord, which passes through a distinct tendinous sheath, across the front of the hock, and upon the carmon bone, becomes connected with the tendon of the flexor pedis. In its action it co-operates with the extensor pedis. The office of this extensor muscle is to raise the foot from the ground, and bring it forward under the body.

The *flexor pedis*, *o*, is situated on the external side of the limb behind. It is spindle-shaped, elongated, with the fleshy part thick. It is one of the principal muscles which bends or flexes the muscles of the foot. As it gets near the hock, it is at once recognised by its large round tendon, which enters a groove at the back of the hock. It is continued down the back of the limb in the same manner as a similar muscle on the fore leg. This is the performing flexor muscle of the hind legs, and aids in bending the pastern, and assists in binding the pastern and coffin-joints.

CHIEF MUSCLES, ETC., OF THE INSIDE OF THE THIGH.

PLATE VII., Fig. 2.

The principal blood-vessels of the groin, *a*. The course of the chief anterior arteries and veins, which extend from *b* to *c*, and include in their range *d* and *e*.

The *gracilis*, or slender muscle, *f*. It is of great breadth, and occupies the chief portion of the exterior surface of the inner part of the thigh, and forms the most prominent part of it. It takes its rise in the lower part of the haunch-bone, and, passing downwards, unites with the *sartorius* (which is situate in the anterior internal part of the haunch), and is inserted with it into the tibia, or lower bone of the thigh. Its action is to bend the leg, and, when flexed, to turn it inwards.

A portion of the muscle which is described at *k*, fig. 1, *g*.

The *peronœus*, *h*. This muscle is attached above to the head of the fibula, continuing its adhesion all along that bone, and below to the coronal surface of the extensor pedis. It is heart-shaped, elongated, and flattened from before backwards; in its action it co-operates with the extensor pedis.

The *popletœus*, *i*. This is situate at the back of the stifle-joint. Its form is short, thick, and triangular. It is attached above to the posterior-external side of the outer condyle of the femur, and likewise to the capsular ligament of the stifle-joint. Below, it is fixed to the upper half of the inner side of the body of the tibia. Its action is to bend the stifle, and, at the same time, to turn the tibia inwards. It also prevents the capsular ligament from being pinched between the bones.

The *flexor metatarsi*, *j*, is inserted in the fore internal side of the limb. Its form is forked at both extremities. It is attached above, in common with the extensor pedis, from the external condyle of the os femoris, and from a broad triangular excavation, visible upon the upper and front external part of the tibia; and below to the head of the large metatarsal bone, and also to that of the small metatarsal bone. This muscle has considerable power. Its action is to flex the hock, and it possesses a tendency to turn the joint inwards.

The *extensor pedis*, *k*, already described at *h*, fig. 1.

The inside appearance of the perforating muscle of the foot, *l*.

The veins of the posterior portion of the leg, *m*.

The ligamentous bands which confine the tendons to their proper place, at the bending of the hock, *n*. These are of much importance to the action of the limb, and, when injured, lameness is certain to ensue.

Close behind the bend of the hock at *o*, from the upper front part of the metatarsal bone, there emanates a thin layer of muscular fibres, enveloped in cellular substance, and which is concealed in part of the tendon of the extensor pedis, with which (about a fourth part of the cannon downward) they form a union, making an addition to its substance. The province of these supplementary fibres is to brace the tendon, and are probably provided so as to prevent its being compressed by the flexor of the hock.

The large cutaneous vein, *p*, which is situate immediately under the skin.

The *inguinal vein*, *q*, is one of the larger veins proceeding from the groin, the formation of which is owing to a considerable branch emerging from the muscles of the thigh, and a superficial or cutaneous abdominal vein, which latter proceeds in a serpentine course along the abdomen, after taking its rise as far forward as the cartilages of the ribs, where its branches form communications with the cutaneous veins of the thorax.

The *femoral vein* is the continuation of the external iliac trunk, below the brim of the pelvis, and becomes the main channel into which the deep-seated veins of the hind extremity pour their blood.

STRUCTURE OF THE HOCK JOINT.

PLATE VIII., Fig. 1.

Of all the points of a horse this is the most important, and with which every possessor of that animal should be conversant; because it is more liable to disease than any other part, and, consequently, the seat of lameness; and, moreover, in a healthy condition no point of the animal is more important; for upon the perfection of its formation, the value and power of action chiefly depend.

The knee in the horse corresponds to the wrist in man, consequently is analogously regarded as the carpus; and, in like manner, the hock corresponds with the human instep, and is technically denominated the carpus, and consists of six bones, viz.:—

The *astragalus*, or knuckle-bone, *a*. It is the uppermost bone of the hock, and that which alone supports the tibia, and distinguished by its formation being fully shaped. It is divided into three surfaces, namely, superior, inferior, and posterior. The superior portion, or pulley-like surface, consists of two prominent semicircular rings, with a wide intervening groove, the whole finely adapted to the two grooves, which are separated by their middle projection, in the lower part of the tibia; and these opposite prominences and grooves are received, and, as it were, mortised into each other. The posterior surface is very irregular and convex, and is received into a concave part near the base of another bone, and with which it is united, by very strong ligaments, to the *os calcis*, or bone of the heel, at *b*. Its sides are flattened, and it projects upwards, and receives into it the tendons of very powerful muscles, which are firmly seated in it. The inferior surface is smaller than either of the others, irregularly flattened, and almost entirely articulatory. It is embraced by the upper portion of the large cuneiform bone. The *extensor pedis accessorius* takes its rise from a pit at the base of the pulley-like process. These two bones rest on two others, namely, the *os cuboides*, or cup-shaped bone, *c*, behind, and the larger wedge-shaped bone in front, *d*. This large wedge-shaped bone is supported by two small ones, *e*, and these two small ones and the cube-shaped bone are supported by the upper heads of the shank-bone, *f*, and the splint-bone, *g*. The cube-bone is seated on the external splint-bone, and the cannon bone—the small wedge-bone—almost entirely rests on the inner splint-bone, which is invisible in our representation, and the middle wedge-bone rests wholly on the shank-bone, *h*. These bones are all connected and bound together by extremely strong ligaments, which prevent dislocation, while, at the same time, they are sufficiently flexible to allow a slight degree of motion among them, and the opposing surfaces on which they move are thickly covered by elastic cartilaginous substance.

The inferior end or base of the tibia, *i*, which is situate between the stifle and the hock. This bone is long, straight, and larger above than below. It is connected with the round bone above, and to the os calcis below.

The *os calcis*, *j*. This forms the posterior projecting part, which is termed the point of the hock. It is of an irregular figure, and is divided into the body and tuberosity.

The *os cuneiforme magnum*, *k*, is situate immediately under the astragalus. It is large and wedge-shaped; the broadest

side is turned forwards, the salient angle backwards, and is flat above and below.

The *os cuboides*, *l*, or cuboid bone, is situate on the outer part of the hock. It is of an oblong form from back to front, and is divided into external, internal, superior, and inferior surfaces.

The *os cuneiforme medium*, *m*, or middle wedge-shaped bone, is situate immediately under the large cuneiform bone, upon the hind cannon bone. The figure and divisions are similar to those of the large bone.

The *os cuneiforme parvum* is situate on the posterior internal part of the hock. It is small and irregular in form. It articulates above with the internal angle of the large cuneiform bone, and before with the same angle of the middle cuneiform; below, chiefly with the internal hind splint-bone, and partially also with the hind cannon bone.

The splint-bone, *n*.

The upper head of the shank-bone, or *metatarsi magnum*.

No part of the frame of a horse is so liable to injury as the hock-joint, not only during rapid motion, but also in the draught, from the weight and stress which it has to sustain. A stronger proof of design could not be adduced in anatomy than the hock; its construction being so skilfully contrived, in the beautiful adjustment of the various points which compose it, and which render it much less liable to disease than might be naturally expected from the heavy duties which it has to perform. This will be manifest from the pulley-like heads of the astragalus and the tibia fitting so deeply into each other, and these being so firmly kept in their position, by extremely powerful ligaments, which are so nicely contracted, that, in addition, they admit the necessary freedom of the hinge-like motion of the joint, and likewise guard against that lateral outside motion to which the joint is necessarily subjected in rapid movements, or passing over unequal surfaces. An inspection of the figure to which we refer will render it apparent, that the weight of the hind quarters is chiefly thrown upon the tibia (see Plate I. *s s*, page 30), and rests upon the astragalus. This weight, however, does not bear perpendicularly, but in an oblique direction; consequently, much of the concussion which would otherwise occur is avoided by the spring-like action which this slanting pressure produces among the various bones of which the joint is composed. This will be more readily understood, by referring to the skeleton, Plate I. We have already pointed out that this joint consists of six bones, all of which are covered with elastic cartilage, and each admitting of a certain degree of motion, which diminishes concussion, by the weight, pressure, and action being diffused among them all, and by this means the concussion is neutralized and rendered powerless. In addition to the cartilaginous covering of these bones, each of them has a membranous coating, which secretes an oily fluid, called the synovia, or joint oil. These bones may, indeed, be considered as so many distinct joints, all of them separated from each other, and protected from injury, and yet united by different ligaments, binding them so strongly together as almost to prevent the possibility of dislocation, and yet affording sufficient motion for the important office which they have to perform. The admirable and powerful structure of this joint is, however, frequently injured by subjecting the animal to an amount of heavy work, greatly beyond what it possibly can perform. To this cause, much of the lameness of the horse may be attributed, and the same brutal treatment will account for the various diseases, which it will be our province to describe, and point out the best means for their cure.

INORGANIC CHEMISTRY.

CHAPTER VII.

THE BLOWPIPE.

Many of our readers may have seen, in the hands of silversmiths, &c., a small curved tube employed in soldering and uniting pieces of metal, but they will be hardly aware that, in the hands of philosophers, this unpretending instrument has become one of the most efficient agents in chemical research, especially in the analysis of minerals. By its aid, we are often able, in a few minutes, to determine the nature of a metallic ore; and even when it does not entirely solve the question, it still throws much light upon the remaining analytical process. The frequency with which we have referred to its employment in the preceding pages, may give some idea of its value. These considerations, joined to its extreme portability, render it absolutely essential for the student to acquire a complete command over this invaluable little instrument.

Fig. 1.

The blowpipe, as adapted to chemical purposes, is shown in fig. 1. *a* is the mouth-piece; *c* the jet-pipe through which the current of air issues; *d* the (moveable) nozzle. The enlarged extremity, *b*, serves to collect and condense the vapours of the breath, and prevent them from choking up the jet-pipe in prolonged blowing. The instrument is generally made of brass, japanned tin-plate, or silver, but the nozzle, preferably, of platinum. The aperture should be fine and perfectly circular, and care should be taken that it does not become clogged up with particles of dirt or soot. The theory of the blowpipe is very simple. If the reader examine attentively the flame of a lamp or candle, he will find it composed of a cone of luminous flame, *b*, fig. 2, within which is

Fig. 2.

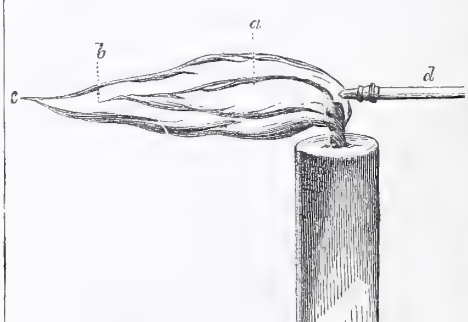
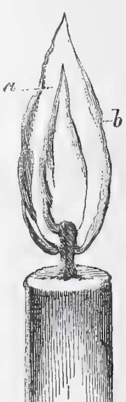


Fig. 3.



a region of inflammable gas, *a*, where no combustion goes on from want of a due supply of oxygen. On the outside of all hovers a thin sheet of pale flame, the seat of the most intense heat. The blowpipe serves to introduce a current of air into the interior of the flame, which now assumes the appearance shown in fig. 3, where *d* represents the jet of the blowpipe, *a* a cone of bright luminous flame, in front of which, from *b*—*c*, extends a region less luminous, but of a higher temperature. These different regions of the flame have distinct properties and uses. The most intense heat is obtained about *c*, sometimes entirely beyond the visible flame, and as there is here a full supply of oxygen, this portion is called the *oxidizing* flame. Towards *b*, on the contrary, the temperature is more moderate; and as there exists here inflammable gas which has not yet met with a sufficiency of oxygen, that element is here

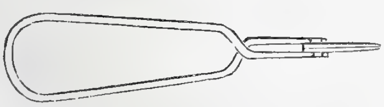
withdrawn from bodies containing it. This region is therefore used for experiments of reduction, and is called the reducing or deoxidizing flame. A gas-burner, or an oil-lamp, is generally used as the source of heat. Experience enables the operator to select the precise part of the flame best adapted to his purpose.

The method of blowing is very important. Were the analyst to blow with the lungs, as is done by silversmiths, he would neither be able to regulate the flame, nor to continue the blast without interruption for the length of time occasionally requisite. To acquire the true method, inflate the cheeks with air, and retain them in that state, breathing all the while through the nostrils. Next allow a little air to escape through a narrow orifice between the lips, and keep up the supply in the cheeks by turning into them, from time to time, a part of what is expelled from the lungs. In this manner a constant and regular current of air may be maintained as long as necessary, the elasticity of the cheek muscles being the impelling power, whilst respiration goes on through the nose. Beginners always blow too violently; the flame must be steady, regular in shape and size, and must not flicker nor roar. If an oil-lamp or candle be used, the wick should be carefully trimmed, and laid sloping a little in the direction in which the flame is to be driven. Gas-burners may be obtained expressly adapted for this purpose, and have the advantage of not requiring trimming; but if the coal-gas employed be not well purified from sulphuretted hydrogen, some inconvenience may be felt in certain delicate operations.

The flame, from whatever source, must be fixed at such a height, that the analyst may be able to hold the blowpipe steadily and without fatigue.

The substance to be acted upon, which is always a minute fragment, is held either in a pair of forceps with platinum points (of which two kinds are shown in fig. 4), or on a strip

Fig. 4.



of platinum foil, or upon charcoal. If a flux is employed, it is fused upon pieces of platinum wire, bent at one end, as shown in fig. 5; a stock of these wires should be kept always at hand, and, of course, perfectly clean. In examining volatile substances, small tubes of the best Bohemian glass, both open and closed at one end, are employed.

Fig. 5.

In examining a substance with the blowpipe, it is generally first heated alone, in a test-tube, in an open tube held obliquely, upon charcoal, and supported in the forceps. All phenomena presenting themselves are carefully observed, such as the odours given off, the degree of fusibility, volatility, frothing, deflagration, the formation of a sublimate, the reduction of a metal, and the behaviour of the substance after heating with test papers. Ultimately the substance is exposed to the flame along with certain reagents, and the result observed. Of these the most important are borax, microcosmic salt (a double phosphate of soda and ammonia), and carbonate of soda. A small portion of the reagent is first taken up upon the wire, and heated until it forms a clear bead or drop; the substance under examination is then added, and the whole again exposed to the flame. When carbonate of soda is employed as a reducing agent, it is best supported upon a thin piece of charcoal. A mixture of carbonate of soda and cyanide of potassium is likewise much used in experiments of reduction. It is generally used either on a charcoal support, or in a glass tube. Nitrate of cobalt is used in solution for detecting alumina, magnesia, and zinc oxide. The first, when moistened with it, acquires in the oxidizing flame a bright blue, the second a rose colour, and the third a green. The bisulphate and nitrate of potash are sometimes used as oxidizing agents.

BEHAVIOUR OF ALKALIES AND EARTHS BEFORE THE BLOWPIPE.

Potash, when moist, gives a faint violet colour to the flame, and turns the red glass formed by heating nickel oxide with borax to a blue.

Soda gives an intense yellow colour to the flame, if moist (decisive).

Lithia, a crimson colour, which, however, is lost if soda also be present. The sample must then be mixed with chloride of barium, and strongly heated. The yellow flame at length diminishes, and a thin green light follows. The sample is then advanced within the edge of the blue flame, when the red tinge becomes manifest.

Baryta gives a momentary pale apple-green tinge. With borax and microc. a colourless transparent bead, which grows opaque on cooling. With carbonate of soda, it is absorbed by the charcoal.

Strontia colours the flame an intense crimson (decisive). The addition of chloride of barium destroys the yellow colour produced by strontia, thus distinguishing it from lithia.

Lime becomes intensely luminous in the flame; behaves with reagents like baryta, but is not absorbed by carbonate of soda on charcoal.

Magnesia, heated with nitrate of cobalt in the oxidizing flame, turns a reddish flesh colour (decisive).

Alumina, treated in the same manner, becomes bright blue (decisive).

Glucina and Yttria form with borax a transparent bead, which turns milky upon cooling, and assume a grey-black colour if heated with nitrate of cobalt.

Zirconia behaves in a similar manner, but becomes intensely luminous when heated.

BEHAVIOUR OF HEAVY METALLIC OXIDES.

Antimonic oxide sublimes with a bluish-green flame; reduced in the inner flame, forms a white coat upon charcoal. With borax in outer flame, a yellow bead, growing colourless when cold; in inner flame a grey bead, which afterwards becomes transparent. With microc. on charcoal it is reduced; the particles of reduced metal give white fumes if heated.

Bismuth oxide fuses on wire, dark-brown when hot, yellow when cold. On charcoal reduced with borax, it behaves very like antimony; with carbonate of soda on charcoal it is reduced, and the metallic particles form a yellow sublimate when heated.

Cadmic oxide is reduced in the inner flame on charcoal, and volatilizes, the charcoal becoming covered with an orange-red coating; with borax in outer flame, a yellow bead, colourless when cold; in the inner flame reduction; with carbonate of soda on charcoal reduced, volatilized, charcoal acquires a brown red coat (decisive).

Ceric oxide, with borax in outer flame a red bead, paler when cold; in inner flame colourless, or milky if in excess; with carbonate of soda on charcoal, no action.

Chromic oxide, with borax in outer flame, yellow when hot, green when cold; with microc. do. in both flames; with nitre or peroxide of barium, a yellow chromate is formed (decisive).

Cobalt oxide, with borax a deep blue bead in both flames (decisive).

Copper oxide with borax in outer flame a green bead, blue when cold; in inner flame a brown-red glass, the colour heightened by adding tin; with microc. in inner flame, a deep green bead, growing red and opaque on cooling; with carbonate of soda on charcoal, reduced, leaving red malleable metallic particles.

Iron oxide, in inner flame becomes magnetic; with borax in outer flame it gives a bead yellow when hot, pale on cooling; in inner flame a dull green glass, which becomes lighter if tin be added; with carbonate of soda on charcoal, it is reduced, leaving magnetic particles.

Lantanum oxide forms with borax a glass, colourless, or of

a very faint rose colour; with carbonate of soda on charcoal, reduced.

Lead oxide melts and tinges the flame blue; reduced on charcoal; the particles of metal first formed sublime and leave a yellow deposit; with borax in outer flame a yellow glass, paler when cold, in inner flame reduced; with carbonate of soda on charcoal, reduced.

Manganese oxide, with borax in outer flame a violet glass; with carbonate of soda on the wire in outer flame, a green bead (decisive).

Molybdic acid melts and smokes in an open inclined tube; with borax in outer flame, a glass, red when hot, pale when cold; in inner flame on charcoal, a brown red glass; with microc. a yellowish-green glass in outer flame; in inner, a glass, deep blue when hot, green when cold; with carbonate of soda on the wire, a clear bead, becoming dead white on cooling; reduced on charcoal.

Nickel oxide, with borax in outer flame, a bead, violet when hot, and red-brown when cold; in inner flame grey; with microc. a red glass, turning pale on cooling; in the inner flame a similar colour, which may be removed by adding tin; on charcoal with carbonate of soda, reduction.

Silver oxide, reduced alone, and with carbonate of soda; and in inner flame with borax; in outer a milky glass; with microc. a yellowish glass in outer flame.

Telluric oxide tinges the flame green, melts, sublimes; reduced on charcoal, forming a white coating; with borax, a colourless glass in outer flame, a grey in the inner; with carbonate of soda on wire, a clear glass, turning milky on cooling; on charcoal, reduced.

Tantalic acid, with borax a colourless glass, which turns opaque if alternately heated and cooled; with microc. a colourless bead, which turns opaque on cooling; with carbonate of soda, effervescence.

Tin oxides are reduced in the inner flame; with borax in outer flame, a colourless glass; on charcoal with carbonate of soda, reduction; particles of metal soft.

Titanic oxide, with borax in outer flame, a colourless glass, opaque on cooling; in inner flame, a glass, first yellow, then violet, growing darker on cooling; with microc. in inner flame, a glass, yellow when hot, purple when cold; with carbonate of soda, effervescence; a yellowish glass, turning an opaque grey on cooling. No reduction on charcoal.

Tungstic acid, with borax in outer flame, a yellow glass, colourless when cold; in inner flame, a yellow glass, which darkens on cooling; with microc. a blue glass, which is turned blood-red on adding oxide of iron, and the blue colour restored by tin; with carbonate of soda on wire, a deep yellow glass, opaque on cooling. Reduced on charcoal.

Uranic oxide, with borax in outer flame, a yellow glass; in inner, a green glass, which is blackened by being alternately heated and cooled; with microc. a glass, yellow when hot, green when cold; in inner flame, a green glass.

Vanadic acid, with borax, outer flame, a yellow glass; inner flame, a glass, brown when hot, green when cold; with carbonate of soda on charcoal, absorbed.

Zinc oxide tinges the flame a brilliant greenish white, turns green if heated with nitrate of cobalt; oxide yellowish when hot; reduced in inner flame on charcoal, forming a white incrustation.

BEHAVIOUR OF ACIDS, HALOGENOUS BODIES, ETC., WHEN COMBINED WITH BASES.

Arsenites and *Arseniates,* if heated in the inner flame upon charcoal, give off the characteristic garlic scent of arsenic. If mingled with cyanide of potassium and carbonate of soda, and heated in a small test-tube, metallic arsenic sublimes, forming a coating on the glass, which is crystalline within. If the bottom of the tube is cut off, and heat again applied, the metal oxidizes to arsenious acid, which adheres to the cold parts of the glass in crystals.

Arsenides behave in a similar manner without cyanide of potassium and carbonate of soda being previously added.

Antimonides, if heated in a tube open at both ends, yield a sublimate of antimonic oxide. If heated upon charcoal, it becomes covered with a white crust.

Borates usually give a green tinge to the flame, if fused upon charcoal with carbonate of potash, and the mass moistened with sulphuric acid and alcohol. If finely pulverized and mixed with three or four times their weight of a mixture of 1 part fluoride of calcium, and 4½ parts bisulphate of potash, they give a momentary green tinge, if supported on platinum wire, and applied to the blue flame.

Bromides added to a globule of microcosmic salt, in which oxide of copper has been dissolved, and heated suddenly, tinge the flame green or blue. If heated in a test-tube with bisulphate of potash, orange vapours of bromine are given off.

Fluorides, containing water, liberate hydrofluoric acid, if heated in a small test-tube. If mixed with bisulphate of potash, or fused microcosmic salt, and heated at the lower end of an open glass tube, in actual contact with the flame, all fluorides are decomposed, and the acid evolved is known by its action upon glass. If silica is also present, the substance is heated upon a slip of platinum foil, contained in an open glass tube, 6 inches long. The blowpipe flame is driven into the tube, which is held in a slanting position, with the substance at its lower end. Fluoride of silicon condenses in drops at the upper extremity, and these, when evaporated by heat, leave white spots of silica.

Iodides suddenly heated along with a bead of microcosmic salt, containing oxide of copper, tinge the flame a rich emerald green. If heated in a test-tube with bisulphate of potash, fumes of iodine are liberated, which may be further examined by means of starch.

Nitrates evolve red fumes when heated with bisulphate of potash. If fusible, they deflagrate on charcoal. If infusible, they give off red fumes on being ignited in a test-tube.

Phosphates do not yield any very characteristic reaction with the blowpipe. A portion of the substance is moistened with concentrated sulphuric acid, and heated (in the dark) in the inner flame, when the outer flame acquires a peculiar greenish blue tinge.

Selenites and Seleniates, when heated in the inner flame upon charcoal, along with soda, give off the scent of selenium.

Selenides, in the outer flame, give the same scent without any addition.

Silicic acid dissolves with effervescence in carbonate of soda, yielding a clear colourless bead, which does not turn opaque on cooling, except the carbonate is in excess.

Sulphates mixed with a bead of silicic acid and soda, and heated in the inner flame, impart a deep yellow or orange colour. Where the colour of the base would interfere, the following test is applicable. A sulphate exposed to the inner flame on charcoal, with two parts soda and one of borax, yields sulphide of sodium. The resulting mass, if moistened, tarnishes silver, and exhales sulphuretted hydrogen. As the behaviour of selenium is similar, its absence should first be determined.

Sulphides heated in an open tube, held obliquely, give off sulphurous acid, which is detected in the usual manner. On charcoal, in the outer flame, they evolve the same odour.

Tellurides heated in a similar manner, yield a white powdery sublimate, which, on the application of heat, fumes and volatilizes.

GENERAL SUMMARY.

Behaviour of Metals.—Infusible: Platinum, iridium, rhodium, palladium, osmium; the last being, however, oxidized in the outer flame; gold and silver fuse without oxidation. Of those metals which may be reduced by the inner flame along with soda, molybdenum, tungsten, iron, cobalt, and nickel, are infusible.

Metallic Oxides.—Infusible: Baryta, strontia, lime, magnesia, alumina, glucina, yttria, zirconia (the six last becoming highly luminous), silica, tungstic acid, chromic oxide, antimonious acid (which is reduced by the inner flame into antimonic oxide), tantalic acid, titanic acid, oxides of uranium, oxides of cerium, sesquioxide of manganese, oxides of zinc

and cadmium (both reduced and volatilized by inner flame), peroxide of iron, oxides of cobalt, nickel, and peroxide of tin (reduced by inner flame).

Fusible: Antimonic oxide, oxide of bismuth, protoxide of lead (reducible), oxide of copper.

Natural Minerals.—Infusible: Quartz, corundum, spinell, tourmaline, piconast, gahnite, olivine, cerite, zircon, cyanite, phenakite, leucite, talc, pyrophyllite, apatite, gehlenite, antophyllite, staurolite, fire-clay, hydrate of alumina, hydrate of magnesia, sulphate of alumina, carbonate of lime, carbonate of magnesia, carbonate of zinc, allophane, cymophane, gadolinite (becomes suddenly luminous), vitreous tin, rutile, titanic iron, tantalite, turquoise, titaniferous iron oxide, chrome iron, native oxides of iron, uranic oxide, tantalite, yttrotantalite, dioptase, chondrodite, topaz.

Slightly fusible at the edges: Felspar, petalite, labradorite, anorthite, nepheline, tabular spar, pyroxene, meerschaum, soapstone, serpentine, mica (granitic), dichroite, epidote, emerald, euclase, titanite, sodalite, calcareous scheelite, heavy spar, celestine, gypsum, fluor spar.

Fusible: Zeolites, spodumen, mejonite, eleolite, amphibole, pyroxene (if excess of magnesia is not present), idocrase, garnet, cerine, orthite, ferrugineous scheeline, boracite, hydroboracite, datolite, botryolite, cryolite, mica (especially if lithia is present), tourmaline (containing potash), axinite, amblygonite, lazulite, haüyne, nosian, eudialite, pyrosmalite.

Changes of colour: Oxides of zinc and titanic acid, white at common temperatures, grow lemon yellow if heated; peroxide of lead, oxide of mercury, and chromate of lead, change from yellow red to black, and resume their former colour on cooling.

Fusible with soda into a clear colourless bead: Quartz, felspar, albite, petalite, spodumen, leucite, labradorite, mejonite, anorthite, emerald, zeolytes, fire-clays.

Fusible with soda, yielding a coloured bead: Dioptase, achmite, lievrite, helvine, axinite, garnet, idocrase, titanic acid

Fusible with soda upon platinum wire in outer flame.—Silicic, molybdic, tungstic, antimonious, chromic, tellurous, titanic acids, oxides of manganese, cobalt, lead, copper.

Reduced by soda upon charcoal in inner flame, metals volatile, and consequently form a deposit.—Oxides of antimony, zinc, cadmium, bismuth, lead.

Reduced in like manner, but form no deposit on the charcoal, the metals not being volatile.—Molybdic acid, tungstic acid, oxides of iron, cobalt, nickel, copper, silver, peroxide of tin, and the oxides of the so-called noble metals.

Bodies unattacked by soda.—Oxides of uranium and cerium, tantalic acid, zirconia, thorina, yttria, glucina, alumina, magnesia, lime, strontia, baryta, and the alkalies.

Bodies insoluble in microcosmic salt.—Silicic acid, peroxide of tin.

Colours produced in microcosmic salt by oxides in outer flame.—Colourless: baryta, strontia, lime, magnesia, glucina, yttria, thorina, zirconia (which, however, in excess, give a milky tinge); *slightly greenish,* alumina and molybdic acid; *slightly yellowish,* tungstic and antimonious acids; *milky* (except in small quantities), tellurous, tantalic, and titanic acids, oxides of zinc and cadmium, peroxide of lead, peroxide of tin. *Green glasses:* oxides of chromium, uranium, protoxide of copper. *Yellow glasses:* oxides of silver, bismuth, vanadious acid. *Red glasses:* oxide of cerium, peroxide of iron, oxide of nickel. *Blue glass:* oxide of cobalt. *Violet glass:* oxide of manganese.

Colours in inner flame.—Colourless beads: baryta, strontia, lime, magnesia, glucina, yttria, thorina, zirconia, alumina, tantalic acid, oxide of zinc, oxide of cadmium, peroxide of tin, oxides of cerium and manganese. *Green beads:* molybdic acid, chromic oxide, vanadious acid, uranic oxide, peroxide of iron. *Red beads:* tungstic acid with iron, antimonious acid with iron, titanic acid with iron, oxide of nickel.

Brown, or brown red.—Oxide of copper. *Blue:* oxide of cobalt and tungstic acid. *Violet:* titanic acid. *Grey:* tellurous acid, oxides of bismuth, lead, silver.

Colours given to borax in outer flame.—Colourless beads: baryta, strontia, lime, magnesia, glucina, yttria, zirconia, tantalic acid, titanic acid, oxides of zinc, cadmium, silver (rendered turbid by "flattering"), alumina, thorina, silica, tellurous acid, oxide of bismuth, antimonious acid, tungstic acid, molybdic acid, peroxide of tin. *Green:* oxide of copper, oxide of chromium. *Yellow:* vanadious acid, oxides of uranium and lead (becomes nearly colourless on cooling). *Red:* oxide of cerium (rendered turbid by flattering), peroxide of iron, oxide of nickel; all become lighter on cooling. *Blue:* oxide of cobalt. *Violet:* oxide of manganese.

In the inner flame.—Colourless: baryta, strontia, lime, magnesia, glucina, yttria, zirconia, tantalic acid, oxides of zinc and cadmium, alumina, thorina, silica, peroxide of tin, oxide of cerium, oxide of manganese. *Green:* chromic oxide, vanadious acid, oxides of uranium and iron. *Yellow:* tungstic acid. *Brown:* molybdic acid and oxide of copper. *Blue:* oxide of cobalt. *Violet:* titanic acid (rendered turbid by flattering). *Grey:* antimonious acid, tellurous acid, oxides of nickel, bismuth, silver.

BOTANY.

CHAPTER XI.

PHYSIOLOGY.—EXTRACTION OF NUTRIENT MATTER.

The mechanical forms which have been the topic of preceding chapters, are subject, by the proper use of their parts, to constant deterioration. Evaporation tends to diminish, and friction to wear them. They are also exposed to exigencies, such as wounds, which call for a latent source of repair. But, especially, foreign particles of matter are required to incorporate with their living substance in order to the progress of growth, and the continual change, characteristic of life, implies a corresponding modification and adjustment of these additions. Accordingly, provision has been made for the recruiting of such wasted energies; and the several laws affecting the conservation of the vital functions of plants comprise what is called their physiology. The life of every individual plant is, of course, ordained with a view to its special well-being; but it is also more generally related to the entire material world, by subjection to the organic laws of the Great Omniscient Designer. But such is the nature of the arrangements entering into the operations of vitality, that the most inventive processes of chemistry cannot approach their silent refinement; nor, after analyzing the easiest combination of vegetable products, is it in the power of the proudest philosophy to effect their junction or reorganization. It is the synthetical principle of life, in short, which retains and subordinates these component elements in a harmonious union or equipoise; and it is only from the moment of its supremacy being impaired, or from its entire extinction, that plants become liable to disease, or altogether abandoned to the control of simple chemical affinities.

The means employed by nature for accomplishing the vital functions of vegetation, include a number of processes, having for their end to supply materials for development, to repair the waste of substance, to maintain the organs in a fitness for their office, and to preserve the whole plant in a state of general health and activity. The following programme will indicate the more important of the series to be found at any time in actual operation:—

I. The extraction of nutrient matter for assimilation.
II. Phenomena of the ascending sap.
  - Ascent.
  - Aeration.
  - Influences of light, heat, and moisture.

III. Phenomena of the descending sap.
  - Descent.
  - Secretions.
  - Excretions.

IV. Miscellaneous phenomena.
  - Excitability.
  - Phosphorescence.
  - Vitality $\left\{ \begin{array}{l} \text{Diseases.} \\ \text{Age.} \end{array} \right.$

I. The extraction of nutrient matter for assimilation, or the conversion of external materials into a substance adapted to the organs it is to nourish.

1. The soil affords a primary location to plants. It consists of granular matter arising from the disintegration of rocks in a state of minute division and intimate mixture, occupying the surface, and it rests on a porous, light, or stiff bed, uncultivated, which is usually denominated the subsoil. Among the general contents of the soil are silica, alumina, and lime; to these mineral ingredients, the organic matters called *humus* fall to be added, and the union of the hard and soft together maintains a certain porosity, admitting of air and moisture, while they also prevent a too rapid evaporation or filtration. The organic may be readily separated from the inorganic by a portion being simply heated to redness in the open air, which dissipates it into gases and other volatile products that escape the observation of our unassisted senses; the other materials remaining after combustion, the earths and metallic bases which form inorganic matter, constitute the ash.

We will speak of the *inorganic* first in order. This class of matters is partly soluble, or saline, and partly insoluble, or earthy.

When boiling rain-water is poured over a quantity of well-dried soil, stirred, and allowed to settle, then poured off and evaporated to dryness, from two to twenty grains of saline matter are obtained, consisting, more or less, of common salt, gypsum, sulphate of soda (Glauber's salts), sulphate of magnesia (Epsom salts), with traces of the chlorides of calcium, magnesium, and potassium, and of the nitrates of potash, soda, and lime. In most countries, after hot weather, slight incrustations of some of these solvents are brought up by evaporation from the porous subsoil; but in Peru, Palestine, and India, more rarely visited by rain, whole plains are whitened over with their deposit. The following quotation from Sonnini ("Travels in Upper and Lower Egypt," 1779, vol ii., chap. xxvii.) is descriptive of the lakes of natron in Lybia:—

"A vast basin of water, the multitude of shrubs that overshadow its borders, the reeds and other aquatic plants that display their verdure on the surface, the herds of deer that assemble there to quench their thirst, and the birds, among which the flamingo rises eminent for the splendour of its plumage, display a smiling picture of nature in this spot, while everything around exhibits only symptoms of her death. When the waters retire, the soil they had inundated is loaded with a sediment, crystallized and hardened by the sun. The thickness of this layer of salt varies according as the water has remained a longer or shorter period on the ground. In places where it has merely wetted for a very short time, it exhibits an inflorescence resembling flakes of snow. It is separated from the ground with iron instruments, and carried away on the backs of camels. Here 1250 tons are collected annually, and much more might be obtained."

The insoluble or earthy compounds of the inorganic matters of soils rarely amount to less than 95 per cent. in weight. Other substances, strictly speaking, enter into the composition; but silica, alumina, and lime form a botanical basis, and, from their relative quantity, a popular classification arises.

Silica is characteristic of sandy soils, which contain not more than 10 per cent. of clay.

Alumina is the proper basis of clay; but silica is always compounded with it. The stiff kind, called *tile*, includes from 5 to 15 per cent. of sand. A *loamy* soil contains from 20 to 50 per cent. of clay; and *argillaceous* soils from 50 and upwards per cent.

Lime, again, determines the chalky qualities of soils. A *marl* contains from above 5 per cent. of carbonate of lime, and when the proportion extends to more than 20 per cent. the soil is *calcareous*. Between barren and fertile soils, lime ranges from about 4 to 56 pounds in the 1000 pounds.

In addition to these inorganic matters, any soil that has been subjected to long cultivation will be found to exhibit, when examined with a microscope, dark fibrous particles of a charred appearance, which undergo slow reduction to a powdery consistence. Such is humus, sometimes called ulmine, which consists of woody and animal fibre in a state of decay—the remains of the vegetable and sentient races that lie buried beneath the soil. But that portion which is obtained from animals must be considered as primarily proceeding from the plants upon which these animals have fed. Humus is present in peat, from 50 to 70 per cent. of weight total. In gardens and old pastures, it sometimes forms a superficial coating; and in stiff clays, from 10 to 12 per cent. has been ascertained. A comparatively small proportion, however, seems necessary to the best arable lands. Oats and rye take no more than 1½; barley from 2 to 3, and wheat from 4 to 8 per cent., respectively.

2. The earthy and saline particles which, in varying combination, everywhere pervade the soil, together with the organic matters they unite, compose the food of plants. Being in general destitute of a power of locomotion, the aliments of plants are necessarily susceptible of universal distribution. In their elementary forms they are reducible to carbon, hydrogen, oxygen, and nitrogen or azote; and inasmuch as these contribute to the earth, no less than to its vegetable and animal inhabitants, the philosophical Schiller sings—

> "Four elements, in one firm band,
> Give form to life, build sea and land.'

These substances are sparingly distributed among inorganic constituents; but when present in the soil, they operate as elements of the soil. Thus it is to silica that the lustrous stems of grasses, oats, wheat, and barley are owing. Alumina possesses the power of absorption for the supply of plants, and gives tenacity also to their texture. Lime, in like manner, enters freely into pea straw, meadow clover, and potato haulm, and perhaps no plant is entirely destitute of it, while many abound in magnesia. The presence of sulphur, iron, manganese, and copper, has been severally detected among plants in varied quantity.

But the elements are peculiarly present in all organized bodies, so that it may be said, the pure ammonia, phosphorus, or potash to be procured of a druggist, has, at one time or other, existed in a plant or animal. The tribes which grow in or near the sea consume a large share of soda, as the saltworts and glassworts, while in the more inland scurvy-grass and sea-plantain, potash predominates. Johnstone ("Elements of Agricultural Chemistry and Geology," 3d ed., p. 11,) estimates the proportion of the organic substances in all vegetable productions which are gathered as food by man or beast, in their dry state, thus: carbon, ½; oxygen rather more than ⅓; hydrogen little more than 5 per cent.; nitrogen from 2 to 4 per cent.; and he embodies the actual constitution of some varieties of the more common crops, when perfectly dry, in the following table, the numbers representing the weights of each contained in a 1000 pounds:—

	Organic.				Inorganic.
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Hay,	458	50	387	15	90
Red clover hay,	474	50	378	21	77
Potatoes,	440	58	447	15	40
Wheat,	461	58	434	23	24
Wheat straw,	484	53	389½	3½	70
Oats,	507	64	367	22	40
Oat straw,	501	54	390	4	51

In drying by a gentle heat, 1000 pounds of hay from the stack lost 158 pounds of water; clover hay, 210 pounds; potatoes, wiped dry externally, 759 pounds; wheat, 145 pounds; wheat-straw, 260 pounds; oats, 151 pounds, and oat-straw, 287 pounds.

3. But for the purposes of nutrition, the mineral and organic elements are never presented pure, but undergo a set of compositions for supplying the demands of the plant. As it is by the agency of the organic elements that minerals are presented in the special condition required, we shall briefly refer to them in succession.

Carbon is characteristic of three groups of substances—the mineral series, as the diamond and anthracite; the carbonates, as lime, and the vegetable, as coal, asphaltum, peat, amber, &c. Sir. H. Davy ("Elements of Agricultural

Chemistry," lect vi., p. 234,) selected that well-known form of carbon, charcoal, and after immersing the roots of mint in a quantity of its impalpable powder, found that no absorption whatever of the powder took place. It was evident from this that carbon is insoluble, and in its solid state does not enter into plants. But it is well ascertained that carbon, when indirectly united to oxygen in definite proportions, forms carbonic acid, not to speak of its other soluble compounds existing in the soil, and henceforth, therefore, the element must be pursued by the botanist under a form of combination.

Carbonic acid exists largely in nature, but in varied measure throughout its different departments. Spring and mineral waters contain it in some considerable degree. It occurs more liberally in union with certain earths and metallic oxides; but the largest proportion of all is embodied in the limestones and marbles, of which it forms nearly 44-100ths. The fermentation of many compounds containing carbon, yields a large quantity. It is also evolved during the process of respiration. Animal putrefaction everywhere disengages it; but when effused by decomposing vegetables, it is associated with the formation of the humic and ulmic acids, which, sparingly soluble in water alone, readily dissolve by the addition of ammonia, forming a rich nutritious compound for plants. Last of all, it is emitted by every act of combustion, whether of oil, wax, tallow, vegetable matter, or coal; and the teeming supplies which are poured out from all these sources, are caught up, in boundless combinations, to assist in the nourishment of plants. Water absorbs it in equal measures, and, from its great density and weight, it is well adapted for being brought into proximity with the materials of the soil. As a gaseous component in the atmosphere alone, its quantity is variable, scarcely averaging 1-20th of its volume. Plants die if deprived of it, and, according to Saussure, an atmosphere containing 9 or 10 per cent. of its amount, will prove fatal to them, though if exposed to the direct solar light they will flourish. The popular legend of the Upas tree is a fiction, a subterranean source of carbonic acid gas being the cause of the sterility which reigns in the poison valley of Java.

Hydrogen is the lightest of all known bodies, and has hitherto resisted every attempt to condense it. It is not found free in a state of nature, but is very abundant in its combined forms, as in the air and water, in the latter of which it is sparingly soluble, 100 cubic inches taking up only about one inch and a half of the gas. It unites with all other elementary gaseous bodies—with chlorine, fluorine, bromine; and with iodine, phosphorus, selenium and sulphur, forming compounds of vast importance and utility. Among the mineral masses, it is traced chiefly in the coaly (vegetable) deposits. The volatile oils of Copaiva, Juniper, Lemons, Black pepper, Savin, and Turpentine are all formed of $C^{10} H^{8}$.

The properties of *oxygen* are best known in its elastic or aeriform state. It supports life much longer than an equal bulk of common air, on which account the name vital air has been bestowed upon it; it is also the principle that sustains burning bodies. There is scarcely an elementary substance with which it does not combine, either by direct means, or by indirect chemical action, giving rise to oxides, acids, and metals, and compounding a great part of the solid globe, and the bodies of its inhabitants. Air contains about 21 per cent. of it, or about $\frac{1}{5}$th in bulk. It also forms with hydrogen 8 parts in weight out of 9, in water—that essential agent, which is not only so plentifully assumed as a menstruum for the materials of plants, but aids in maintaining their pliancy, and serves to bathe them in fertilizing dew. Oxygen requires about 27 times its own bulk of water for solution in that medium; and in the interior of plants, is resolved into other gaseous forms, to be worked up according to the requirements of species.

The synonym azote, which is convertible for *nitrogen*, implies that, by itself, it is fatal to organic life. It enters into the composition of a large number of important compounds. Water dissolves but a limited quantity of it. With the volumes of air, it constitutes from $\frac{79}{100}$ to $\frac{80}{100}$, and tends to moderate the high action of the oxygen with which it is mixed, rather than chemically compounded. With hydrogen again, it forms the alkali ammonia when gaseous, in the proportion of 14 to 3. It is a question of much intricacy, how the nitrogen of the air passes from its inert condition, into that state which is active in plants, as one of the most valuable of fertilizers; but, according to a recent determination, out of 100 pounds of atmospheric air, not more than a $\frac{1}{4}$ grain of ammonia, has been obtained. The inconsiderable supply from this source, is assisted by the escape which it makes from the burning lava of volcanoes. Decomposing vegetables give off the whole of the nitrogen they contain in the form of ammonia, and it is even more abundantly produced by the decay of animal tissues, as hoofs, horn, &c., It is a constituent in most of the vegetable alkalies, but no part of the vegetable acids. According to Payen (Comptes Rendus, 1838, p. 132), it is almost entirely confined to the juices and secretions of plants, in which indeed, the combinations known under the chemical names of gluten, fibrin, albumen, casein, &c., are chiefly manifested.

There is still another class of combinations of great importance in Botany, on account of the respects in which they are remarkably conducive to vegetation, arising from the compounds which nitrogen makes with oxygen. Among the two oxides and three acids which are thus produced, nitric acid stands conspicuous. It is invariably supplied to the roots of plants in a state of combination; usually in connection with potash, soda, or lime, of which it forms, respectively, nitrates. The refreshing face worn by the green fields after the fall of a thunder shower, is due, in one or other of these forms, to the nitric acid electrically produced by the chemical union of nitrogen and oxygen, which existed before merely in a state of mixture in the air; and the luxuriance of tropical countries is perhaps not a little indebted to their more abundant, but awful visitations of lightning.

All the elementary bodies we have referred to, constitute the great bulk of plants. In binary compounds, they form oil; in ternary, gum and starch; in quaternary, albumen and fibrine. The disengagement of any one element, only fraternizes with many more, so as to restore and equalize the measure of universal vegetation; and the disunions and combinations which are constantly going on, display, even in the solitary places, a scene of chemical agency, which it is astounding to conceive.

4. The aliments necessary to any given plant are of equal value, and the paucity or absence of any one of them will render the soil infertile for all those vegetables to which that principle is indispensable. Obstacles may exist to the solution and reception of the nutritive principles contained in a soil, by their remaining chemically combined through a privation of matters required to disengage them. If, for example, the application of phosphate of lime should augment a crop to which its absorption is requisite, we may conclude that to have been the salt which was deficient in the soil; but the privation of any other necessary principle would have prevented the lime from producing its effect. The expression *telluric conditions* comprises at once that chemical, physical, and economical state of the soil, according to which the quantity and weight of plants are capable of being diminished or increased.

In addition to a proper constitution of the soil itself, it ought to afford a free access to atmospheric air and water, and scope for the roots to branch out and seek nourishment in all directions. A fertile soil removes from the atmosphere, by means of the plants growing in it, more carbonic acid and ammonia than a soil less fertile; and when these are added to the mineral aliments contained in the soil, it is fitted to become more productive. The maximum of products is attained when the telluric and atmospheric conditions are simultaneously fulfilled, that is, when their aliments are present in sufficient quantity, in suitable proportion, and for a proper duration. And a soil replete with its measure of mineral and atmospheric matters, is incapable of being further enriched by the addition of a quantity of the same substances, since the natural limit to the growth of plants determines and fixes their capacity.

Fertility, therefore, is a consequence of nutrition. The words, fertile or rich, infertile or poor, express no more than the relative proportion, with regard to quantity or quality, of the principles necessary to the growth of vegetables. A soil will be fertile for any particular species of plant, if it contains the nutrient substances essential to it in suitable relations

and in practical order. Of two plants of the same species, having at their disposal unequal quanites of such nutriment, the periodic weight of that will be greatest which has received the greater nutrition. The more rapid the development, the more definite is the nourishment required.

5. It is to be remarked farther, that for passing into the vegetable organism, the medium in which all the nutriment of plants is conveyed, is a gaseous or aqueous solution. It is easy to comprehend how a subtle gas may penetrate the cells, vessels, and interstices of plants; but the difficulty attached to the introduction of the solid aliments, may be also dissipated, if we can realize the attenuations to which they are reduced, and the rareness of the combinations consequent on their absorption. Solutions of gum and sugar have been tried, and found, in part, to permeate the tissues, but a palpable residue was always left unemployed, and if of sufficient thickness to clog up the pores, the plant withered and died. Even in saline solutions of specific strength, only a small proportion of the salts were taken up. The solid aliments, indeed, constitute a fixed capital in the soil; and it is the portions of them made fluid, and nicely attenuated and combined by degrees, which represents their immediate investment. Some matters are soluble in slow and delicate portions, by rain water; others by rain water containing carbonic acid, an ammoniacal salt, or other quality. The researches of Berzelius established the fact, that silex, dense and hard as it is, is capable, to the requisite amount, of comminution by this solvent power; and we know that by a train of decompositions for the production of silicic acid, it is copiously deposited in the stems and leaves of sugar-cane, &c. From the nature of the case, the limpidity must be perfect, to become available for plant sustenance; and the successful growth of plants is, to a large extent, so dependent on this law, that of two fields, a difference in the states of solubility shall cause a difference in the products. The average temperature remaining the same, even the crops on the same field in different years, will increase within a certain limit in the year that is more humid. The harvests of different years thus vary, because plants receive from the soil less water in hot and dry years than in damp.

6. Let us look now at the organs which are appointed to receive the nourishment as it is offered. The root proper does not appear from its epidermal envelope, to be possessed of any absorbent power. Duhamel had remarked that the soil surrounding a plant was exhausted at the extremities only of the roots, when Sennebier, taking three carrots of equal size, immersed one in water, and merely dipped the tail of another, with the result of an absorption of equal quantities of fluid in both cases; but when the lower extremity of the third was inverted in the vessel, so as to be exposed above the surface, no absorption whatever ensued. Any spindle-shaped root may be found to serve in this experiment, from the spongioles being attached at an extremity.

It is in fact, by the spongioles, or thread-like fibrils depending from the roots, that regular absorption takes place. The production of these absorbent mouths invariably keeps pace with the prolongation of the root, and the root itself never ceases to be proportionate to the lateral extremities of trees. The growth of the root, by ranging from a horizontal to a downward direction, is uniform with the progress of the whole plant; and as by one act of this relation, new portions of soil are constantly attained, so the rain which is shed from the branches, is made to soak through the ground at the exact distance where it may readily meet the spongioles. In these adjustments, we behold a harmony between the soil, the plant, and the firmament, which allows of resolution only on a principle of pre-arrangement.

The cellular construction of the spongiole fits it for imbibing the fluids which are brought in contact with it, and also for absorbing the carbonic acid and ammonia which may be liberated in the soil. The number of spongioles, and the manner in which they are disposed, determine the capacity of the roots for the nutritive matters furnished by the soil, subject to a modification not well ascertained, arising from their relative densities. When the fibrils of the root are of equal dimensions, they cannot succeed so well, near or following each other, as roots with spongioles of unequal length, drawing their nourishment from different depths. The diameter of the pores of each spongiole is, of course, the fixed limit of its absorbent powers.

It is necessary to observe farther, that while a general power of absorption is incidental to the root, a selecting function seems in some sort to belong to it also. Where the natural arrangements have been displaced, the mechanism of the operation seems irrespective of the deleterious qualities which an aliment may contain; for instance, the poisonous solutions of zinc, copper, barium, and baryta, are readily absorbed by adult plants, if presented. This general power of absorption possessed by plants, exposes them to occasional danger, even when the food is salubrious. The extension of roots in a highly nutritive soil, is attended in the first instance with a luxuriance of vegetation, which may be beneficially checked, either by cutting short the roots, or by pruning the young shoots; but when a superabundant supply continues, the death of the plant becomes inevitable, as may be often seen in the naked trunks standing contiguous to dung-steads or ill-conditioned drains. In these cases, nature would have denied the *seed* to that soil.

Naturally considered, indeed, food is the requirement of plants, according to their particular nature, condition and circumstances, and each kind appropriates what belongs to itself, so as to acquire the endowments peculiar to its specific character. Wheat assimilates azotised matter, and corn, phosphate of lime. Though it is difficult to say to what extent, if any, this may be a true power of discrimination, it is placed beyond doubt, that plants appropriate at least with a respect to the earthy constituents which form the basis of their solid parts. If poor soil be placed on one side of a root, and rich soil on the other, the root not only refuses to pasture on the poor, by a law easily understood, but extends its members in the direction of the abundant wealth, with an unequal measure, as if to make up for the deficiency it had already met. This effect is rendered still more emphatic, when a subterranean fence is formed around the root. In that case, the rootlets penetrate to the bottom of the obstruction, and then ascend on the other side, till their natural level is attained. See the experiments of Dr. Daubeny, Trans. Linn. Soc. xvii. 253, 266.

7. We will now draw to a conclusion by glancing at the practical ends which lie within the compass of this brief sketch. To apply the preceding principles is, in fact, to seek to confirm by facts and establish by experiment the phenomena of agriculture. Many important conclusions might be realized by the result of operations in the field, if done with those abstract precautions which are required to raise them above the reach of fallacy. For this purpose, the science and the art must go hand in hand; for, if disjoined, each conduces to mere speculation, and the practical part, it must be allowed, has often spent itself in idler dreamings than those on which science ventures.

It is in this point of view that the physiology of plants derives much of the promise with which it is invested. It was said, at the outset of the chapter, that all the functions of plants called *vital* are incapable of being reduced to any ascertained exercise of the great physical laws; while, therefore, their proximate principles and ultimate constituents belong to the range of chemistry, it does not appear, in the present state of our knowledge, they can be made a safe groundwork of botanical classification. "If it is true," says Lindley ('The Vegetable Kingdom,' 1846, pref. xiv.), "as appears to be admitted, that such principles as Caffeine and Theine are identical, and that oils of Anise and Tarragon are chemically undistinguishable, it is clear that these substances can have no connection with structure." At the same time, it is highly probable that the prosecution of such subjects may yet clear up many of the difficulties which lie shrouded in darkness, and may contribute to place vegetable research on a firmer and sounder foundation. The substances which play so essential a part in inorganic nature, had no sooner been recognised in living beings than a new domain was opened up for separate and more enlarged survey. Professor Müller of Berlin has ably vindicated the claims of physiology to the position of an independent science; and under the contributions which daily teem and swell its dimensions, it may be regarded as just arisen out of chemistry,

as natural philosophy, astronomy, and mathematics have severally succeeded each other, from remote time, in the order of their mutual relations.

1. The principle of *tillage* arises from the complex decompositions required to liberate from the soil the constituents of plant life. With this view, it consists in breaking up portions of pasture land to render productive the provision of substances contained in it. The processes of *ploughing*, *harrowing*, and *hoeing* have for their respective objects to lay open the soil; and pulverization by *rolling* is a kindred operation, designed to crush the clods into a greater surface for the concurrent action of air and water. After an old surface has been exhausted, the raising of the subsoil, called *trenching*, proceeds upon the mechanical plan of offering a new soil to the agency of the elements. To the same class of methods for recruiting lands exhausted with crops or over-run with weeds, belongs what is called *fallow*, which, by repeated ploughings for a whole year, allows the corrupt growth to be buried, and the air and rain-water to infuse a fresh stock of carbonic acid and ammonia. Towards the beginning of last century, an exclusive system called the New Husbandry was founded on these principles by Mr. Jethro Tull, who introduced horse drill and hoeing machines to supersede manure by simple labour. The seed having been sown in rows wide apart, and the intervening spaces kept regularly stirred, all the humus was converted into soluble extract, which made the plants thrive while the supply lasted; but the first success ceased at last to be sustained. Though many crops may be thus taken, each forms a sure step to the further impoverishing of the soil, which ultimately refuses, for a greater or less period of time, to repay the cost of seed and labour.

2. But to produce crops more rapidly, and obtain for a given surface a greater amount of vegetation, *manure* is imparted for supplying the substances which the soil itself may not contain. Every plant posesses a certain quantity of the elements of the soil, and the plant itself, if made soluble, would be a direct means of restoring the extract which has been made by it. But as a part of every sown crop is retained for consumpt, a substitute must be found for that which is taken away, in the shape of a pabulum for the next plant. Various azotised matters which conduce to the muscular tissue of animals, and unazotised matters containing the mucilage, starch, and sugar auxiliary to respiration and fat, must be comprised among the properties of manures. Both mineral, vegetable, and animal matters, in a state of decomposition, are consequently employed to recover that fertility which is diminished by the annual removal of crops. Liebig ("Zeitschrift für Deutsche Landwirthe," and "Journal d'Agriculture Prattique," No. 3, 1855), thus explains the rationale of their action:—"The vegetable and animal matters and the excrements of animals become decomposed; in consequence of this decomposition, the nitrogen of the nitrogenous principles of these matters is transformed into ammonia; a small quantity of ammonia is converted by oxidation into nitric acid. Animal manure, consequently, introduces into plants, not only the mineral matters which the soil should furnish them, but also the nutritive principles which plants obtain from the atmosphere. The gradual decomposition of the vegetable and animal substances in farm-yard manure produces carbonic acid and ammonia; these substances form in the soil an active source of carbonic acid. Thus the air and water contained in the soil become richer in carbonic acid. By adding atmospheric aliments, by means of ammoniacal salts of humus, to those which the plant attracts from the atmosphere, we increase the effect produced in a given time by the mineral substances contained in the soil. Consequently, we obtain a larger quantity from an equal surface. It is even possible to obtain in one year as much as would be produced in two years without this addition. The absorption of the elements furnished by the atmosphere to the plants remaining the same, the crops will remain in direct ratio with the mineral nutritive matters introduced into the soil by the manure."

Our space will not allow us to enter on the particular economy of manures at present; we will therefore content ourselves by giving the annexed table, which exhibits a summary of the principal kinds.

MINERAL MANURES.

Lime, marl, shell, chalk.
Sulphate of magnesia (gypsum).
Sulphate, nitrate, and carbonate of soda.
Chloride of sodium.
Nitrate and carbonate of potash.
Ammoniacal liquor of gas-works.
Soaper and bleacher's waste.
Coal-dust and soot.
Sulphur.
Powder of burned clay.
Sand.
Scourings of roads and ditches.

VEGETABLE MANURES.

Sea-weeds and their ash, kelp.
Charcoal and vegetable ashes.
Yeast.
Fermented weeds.
Green crops.

ANIMAL MANURES.

Urine.
Night soil.
Cow and horse dung.
Pigeons' dung.
Guano, or dung of sea fowl.
Bones.
Blubber, oil, blood.
Leather and horn scraps, hair and wool.

COMPOSTS.

Urate, compound of urine and gypsum.
Dung and lime.
Farm-yard manure.

The application of these manures to the class of crops usually included under the term cultivated, which implies their subjection to annual stimulation and extensive reiteration, may lie at the bottom of the cause which seems to place an opposite assortment of plants out of the range of their useful action. The family of Orchids seems insensible to their influence in any form yet tried; and to Cherries, Plums, Peaches, Nectarines, and probably to all trees which yield gum in their barks, especially stone fruits, they require to be very sparingly offered. Coniferous species of every kind are injuriously affected by manure.

3. *Rotation*, consisting of alternate farming and succession crops, is required to equalize, in some way, the constituent materials of plants. The law assigned for manures is that of *compensating* the change introduced into the soil by the extraction of its materials in the crops raised upon it; but rotation seems in reality to proceed from a different cause, though usually assigned to the first. No doubt one plant requires ingredients which another may not need, and the growth of the first kind extracts a certain proportion of its own constituents out of a soil which the second kind varies by a different share of the elements that remain; but that the question is wider than the supply of mere nutrition in a soil that has been exhausted, appears from this, that the highest administration of skill has not hitherto been able to continue from the same ground equal crops of the same grain, without the intervention of crops of a different kind. Notwithstanding a liberal and judicious application of manure, the land, under a succession of the same crops, becomes, as the farmers say, *tired*, so as to exhibit in the crop, first signs of unhealthiness, and then of failure. It is matter of experience, in short, that besides the exhaustion occasioned by vegetation, all crops have a specific effect on the soil, according to their kind; and whether connected with a practical impossibility of hitting the exact proportions in a manure, or with an unascertained law of nutrition, or with a natural tendency in plants not indigenous to degenerate in a foreign soil, the fact is certain with respect to a majority of the crops that are raised.

The cycles to which the animal world is subject, seem indeed to appertain to the vegetable kingdom. It is well known that when the Pine forests of Sweden are burned down, a growth of Birch wood takes place, until, at length, the Pines again spring up; and along the shores of the Upper and Middle Rhine, the oaks of centuries are seen to sicken and spontaneously concede to the Beech, or the Beech slowly alternates with the Pine. The peculiarity here is, that these are strictly natural processes, where neither manual cultivation nor manure is concerned; and the seeds of the different species probably lie dormant, until the chemical constitution of the soil, receding from one and then predominating to another, gradually educes and supplies the wants of both.

The same thing is substantially matter of familiar observation with domestic plants. The peat mosses of Scotland everywhere exhibit a disinclination to the Sauch, Birch, Fir, Oak, and Hazel, whose remains abound in these extensive tracts. Peaty soils laid down to grass are found almost invariably to produce the Woolly Holcus. Thus also meadow grasses, if cut before the blossom is faded, will spring up again, but if allowed to ripen, the crop becomes later and later, and the best grasses die and disappear. When allowed to run to seed, the use of manure does not avert the decreasing amount of seed, year after year on the same ground: it is seeding that forms the climax of each deterioration of this kind; for if mown before the seed be formed, no diminution of the crops is apparent, even when the species has been repeated on the same soil. Irrigation and *feeding off* the meadows, are found to be the only known methods of restoring the power of production when lost.

Other facts of a similar nature have been found. In general, plants with a naked stem and few leaves, bearing farinaceous seed, thrive best after leguminous plants, with a branching stem, as peas and vetches; or after esculent roots, which strike into the ground, as turnips and parsnips. Wheat and clover always follow each other well, but beans make an inferior succession, and must be forced. Rye, oats, and roots may be tried, but rape, flax, and potatoes require a more distant recurrence on the same ground. From these circumstances, confirmed by universal experience, the different systems of rotation take their rise—the triennial, the Norfolk, and the occasional, suggested by the nature and condition of the soil. This subject is of paramount importance to the farmer, whose interest lies in the cultivation of his land according to the most approved principles.

4. The last but not least manifest of the corollaries we shall deduce, embraces the theory of *Planting*, or the operation of depositing in the soil, the roots of a plant which has been previously removed, and of arranging it with a view to vigorous growth in a new situation.

(1.) The mechanical art must be pursued with an immediate reference to the strict preservation of the spongioles. These being the organs of absorption, by which food is received, their tissue, tender and naked, and constructed to act in humid darkness, it is obvious that their freedom from mutilation and drought is essential to their subsequent success. Although trees, raised from seed and never moved, become firmer and larger than those that are transplanted, yet the establishment of nurseries to raise plants, is found, on calculation, to conduce to the quicker attainment of a certain growth, than those which remain on the spot where they were sown; and nurseries, therefore, have become an economical means of preparing for every plantation of any extent. The excellence, however, of the art of planting, is called prominently into view, by the necessity of producing a full and ready vegetation in wastes, where the leaf may at once vibrate to the breeze, and a mass of dense arborescence diffuse its shadows of green over the new-made landscape. The operation is begun by undermining the roots in a trench, and with the aid of a blunt-pronged fork, loosening them, taking care to separate and support them as occasion requires. The cutting of roots shorter, is sometimes practised, as well to improve the appearance and vigour of a plant, if restrictively potted, as to stimulate the production of new spongioles, for insuring the success of their after removal. The excavation for their reception ought to be easy in circumference, with the bottom somewhat convex, and the depth adjusted to nature: and when the insertion is made, the roots must be regularly disposed, and afterwards plentifully watered, when the fine soil is nearly all filled in. Early budding trees ought to be removed in autumn; in wet soils, apt to throw the roots out in winter, spring planting is to be preferred; but November, or as soon as the leaves have fallen, is the proper time in most cases. Beech plants will thrive if planted in the month of April.

(2.) The success of planting ultimately depends on its relation to the soil or the locality to which the tree is transposed. Without regard to this adaptation, no care or skill in the planting can suffice. Professor E. Forbes observed in Syria, that the serpentine rocks usually grew scattered pines, while the limestone was thickly clustered with oaks and a luxuriant underwood, with occasional pines in clumps. Mare's Tail, with us, springs up abundantly in water-courses where silica is collected; Red-broom rape adorns the basalt ridges, and Pasque flower waves from its chalky mound. We subjoin a descriptive list of timber trees which may be useful.

Oak, Quercus robur, and Q. sessiliflora; any soil, not wet or chalky, within 800 feet above the level of the sea, but flourishes on a sloping clayey loam.

Beech, Fagus Sylvatica; on calcareous soils or gravelly and sandy loams.

Elm, Ulmus campestris, U. glabra, U. montana; any soil within 500 feet of sea level; attains a large size near the banks of rivers.

Ash, Fraxinus excelsior; a gravelly loam, or any dry subsoil not stiffened with clay.

Plane, Platanus orientalis; rich warm soil, rather moist, but not retentive.

Sycamore, Acer, Pseudo-platanus, A. Platanoides; moist deep soil; withstands the sea breeze.

Chestnut, Castanea vesca; deep sandy loam.

Walnut, Juglans regia; deep loam with a subsoil, pervious, not clayey.

Birch, Betula alba; dry sandy or gravelly soil.

Lime, Tilia Europæa; soft deep loam, in low or moist situations.

Horse-chestnut, Aesculus hippocastanum; deep loam, sheltered.

Poplar, Populus alba, P. canescens, P. nigra, P. tremula, P. fastigiata, P. græca, P. monilifera; any soil, especially if deep and inclined to moisture.

Mountain ash, Pyrus aucuparia; any soil except wet clay, adapted to high altitudes.

Alder, Alnus glutinosa; moist or swampy soil.

Willow, Salix; most of the numerous species prefer moist soil.

Pine, Pinus sylvestris, P. laricio; on the warmest sides of mountains, especially in mountain glens. P. pinaster and P. strobus court a somewhat lower exposure. Spruce, Abies excelsa, A. alba, A. rubra, A. nigra; deep moist soil in low situations.

Larch, Abies larix; thin mountain land, where the subsoil is not retentive.

All coniferous plants dislike both chalk and stiff clay, or deep strong loam.

ON THE MANUFACTURE OF NITRATE OF COPPER AND OTHER METALLIC NITRATES.

The ordinary mode of preparation of nitrate of copper, intended for dyeing purposes, is by dissolving copper in nitric acid. By this plan an excessive waste ensues, as a great portion of the acid is decomposed into nitric oxide, and evolved in red fumes. To avoid this, let atomic weights of nitrate of soda and sulphate of copper be pulverised, adding a little water. They are then melted together, their water of crystallization, in addition to that added to the mixture, causing them readily to form a saturated liquid. So soon as the *slightest* appearance of red fumes is perceived, the composition is to be removed from the fire, and allowed to cool. The mass will then be found to be a mixture of nitrate of copper and sulphate of soda; the latter may be evaporated by crystallization. If the nitrate is intended as a mordant for dyeing, this is not necessary, as the latter will be exhausted by the goods, leaving the sulphate of soda nearly pure. The nitrates of iron, zinc, and many other metals, may be prepared in a manner exactly similar; indeed, the process will answer in all cases where the metallic sulphide is soluble.

ON THE MEASUREMENT OF WATER DELIVERED THROUGH LARGE (OR WIDE) ORIFICES.

By M. Morin.

(From the Academie des Sciences.)

I propose communicating, successively, to the Academy, the results of the experiments made by me some years ago, at the powder mill of Bouchet, on various hydraulic motive powers; either by order of the Minister of War and with reference to the powder department, or for the purpose of examining questions submitted to the decision of the Academy itself.

In experiments on hydraulic motive powers, the most delicate portion, and that most subject to error, is the measurement of the quantity of water expended. Local circumstances, forms, or shapes, the arrangement of flood-gates, exert on that quantity great influence, which, as yet, has been too little studied, and the inexact appreciation of which has frequently led the most conscientious observers into serious errors, to which may be attributed, very frequently, the manifest exaggeration of certain results announced with the most perfect sincerity.

In order to place myself out of the reach, as far as it depended on me, of such errors, and to establish with some certainty, or at least with a sufficient approximation to it, the ratio of useful effect produced by the motive powers submitted to experiment, to the absolute amount of water expended, I endeavoured to determine upon a mode of measurement beyond the reach of controversy, which was somewhat difficult.

For this purpose, I first reflected whether I could measure, with sufficient exactness, the quantity of water supplied by an overshot-wheel flood-gate fixed at the head of a canal, or race, in which the motive powers to be subjected to experiment were to be placed. This flood-gate is equal in width to the head-race, which is constructed of masonry; it is inclined from above, downwards at an angle of about 65 degrees to the horizon; its upper edge has an acute angle up-stream, and is rounded off down-stream; it is 0·08 m. thick. Two racks, each of 0·05 m. wide, reduce the clear width to 2·017 m.

In order to estimate the volume or quantity of water that passed over this flood-gate, the tail-race, which was constructed of masonry, with a rectangular section, was closed below by a vertical dam of plank, in which were made three openings; to these were fitted wicket-gates of about 0·300 m.* square, of thin sheet iron, of about 0·005 m. in thickness, sliding in front of the orifices, which were formed with sharp edges, similar to those made use of in the experiments of Messrs. Poncelet and Lesbros. These small sheet iron wicket-gates were, by means of screws, worked by hand; rods, with marks showing the level, were placed in front of the overshot-wheel flood-gate and the wicket-gates, in order to show and to verify the invariableness of the levels.

From this short description, it may be readily conceived, that by making simultaneous observations at the overshot-wheel flood-gate, and at the orifices with thin sides, the supply, or quantity delivered, by the two kinds of orifices might be calculated, by means of the very precise results of the experiments of Messrs. Poncelet and Lesbros, and which were evidently applicable, with all desirable exactness, to the case in question.

But these experiments, undertaken on canals of great dimensions, which had vast basins, subject to the effects of the winds, and whose level it was difficult to regulate perfectly by means of an ordinary mill flood-gate, could not possess a degree of exactness comparable to that of experiments made under more favourable circumstances. In order to examine into the whole together, and to disengage the results from accidental influences, we have re-produced them by a graphic construction, taking the values of the charge† H, on top of the flood-gate, as abscissa, and those of the coefficient of the supply or delivery as ordinates.

In examining the table of the results, and, above all, the curve which represents them, it is seen that the values of the coefficient of the supply or delivery increase rapidly with those of the charge H, on the ground-sill of the orifice, from H = 0·03 m. and 004 m. up to H 0 10 m., a term beyond which they still continue to increase, but more and more slowly.

If, to compare these results obtained with a flood gate of 2·017 m. in width, equal to that of the head-race, and placed in the before-mentioned circumstances, with those which relate to a flood-gate of 0·20 m. wide, to complete contraction, we determine, by means of the figure, the values corresponding with the *charges* observed, in this last case, the following table may be formed, which we limit to the charges with which we have operated :—

Width of Orifices.	Values of the co-efficient m, of the formula $Q = m\,L\,H\sqrt{2\,g\,H}$, For the values of H equal to					
	0·04 m.	0·06 m.	0·08 m.	0·10 m.	0 15 m.	0 20 m.
0·200 m.	0·407	0·401	0 397	0·395	0·393	0·390
2·017	0·264	0·355	0·418	0·448	0·469	0·482

It is seen that for small charges, this flood-gate, of 0·08 m. thick, produces a notable diminution in the supply or delivery, although the construction may be nearly annulled on the vertical sides of the orifice. This effect is analogous to that observed by Messrs Poncelot and Lesbros on small overfalls passing through a shute. We know, in fact, that in the cases in which the contraction is nearly null on the sides, these observers found the following values of m :

Charges on the upper side of the overfall...	0·04 m.	0·06 m.	0·10 m.	0·15 m.	0·21 m
Values of m.............	0·246	0·271	0·308	"	0·324

These values, which, for small charges, make a very near approach to those we have obtained, show that the diminution of the supply or delivery depends, in both cases, on the same cause, on the resistance of the side or wall of the flood-gate, or of the shute. We notice, in fact, that in small charges, the fluid vein wets and follows the surface of the flood-gate; but in proportion to the increase of the charge, this influence of the sides or walls diminishes, and soon indeed the fluid vein detaches itself completely from the upper edge, which is sharp up-stream, and the resistance of the surface of the flood-gate ceases to be felt, whilst at the same time the suppression of the lateral contraction continues to exert an increasing influence on the augmentation of the supply or quantity delivered: whence it results that the co-efficient of the supply or delivery increases.

Such is the natural and simple explanation that may be given of the smallness of the values of the co-efficient of the supply or delivery for the small charges, and of their magnitude for the large charges observed in our experiment.

Notwithstanding the care taken in the execution of these experiments, the local causes and circumstances mentioned did not permit us to approximate nearer than $\frac{1}{18}$th or $\frac{1}{20}$th; but the sketch shows, nevertheless, by taking them as a whole, the gradual and continual progress of the increase of the co-efficient of the supply or delivery, and, until new and more precise researches are made, I think we may, in applications to analogous cases, adopt with sufficient accuracy for practice, the values deduced from the sketch, for the co-efficient of the supply or delivery, viz :—

Charges on the Sill of the Overfall,—in metres.

0·04, 0 05, 0·06, 0·07, 0·08, 0·09, 0·10, 0·12, 0·14, 0·16, 0·18, 0·20.

Values of the co-efficient m.,—in metres.

0·264, 0·313, 0·335, 0·390, 0·418, 0 437, 0·448, 0,460, 0·467, 0·472, 0·477, 0·482.

These values which, for charges exceeding 0·10 m., are much greater than those which have been, up to this time, adopted for similar cases, show that flood-gates, arranged like that made use of by us, which is the case with many horizontal wheels, deliver more water than is generally admitted to be the case; and that, in experiments on hydraulic motive powers, we are liable, for want of a good method of measurement, to estimate the supply or delivery of water at one-sixth or one-seventh below the real amount, and, on the other hand, very much to overvalue the useful effect.

It would therefore be desirable that new special experiments, on large flood-gates, of the proportions most in use, and arranged as is most customary, should be made with proper accuracy. The preparation and arrangement of the necessary apparatus require considerable outlay, convenient localities, and a combination of means and circumstances such as are rarely to be found, and these difficulties make us regret that the experiments already made with so much care and precision, by order of the Minister of War, at

* The *metre*, which is the measure adopted in this paper, is equal to 39·371 English inches.

† The word *charge* throughout this paper, is intended to designate the depth of water on top of the flood-gate.

Metz, at the expense of the Government, from 1827 to 1834, with a view to the wants of the Artillery and of the Corps of Engineers, should not yet have been published, or even communicated to these corps.

Experiments on an Orifice with the Charge on the Summit.

Although the *ensemble* of the results obtained with the overshot water-wheel flood-gates, enables us to determine with sufficient exactness, at least for practice, the amount of water actually supplied or delivered in the experiments proposed, on hydraulic motive powers, I have thought it best to make use, for this purpose, of an orifice with the charge on the summit, so that the height, and, consequently, the area of the orifice remaining the same, the charge on the centre being alone exposed to slight errors of measurement, enters into the calculation of the supply or delivery, but as under a radical of the second degree, and the influence of these errors diminishes when the charge increases. For this purpose, I caused to be made on the same race or canal, an orifice of 1·496 m. in width, the vertical sides of which were 0·16 m. and 0·165 m. from the sides of walls of the canal, and as the movements or risings of the flood-gate were very slight, when compared with these distances, the contraction might be considered as nearly complete on these sides, as well as on the upper and lower sides. The determination of the actual supply or delivery by this orifice, was made, as has been before explained, by means of small wicket-gates, whose greatest opening was 0·300 m.

The examination of the results obtained, above all, their graphic representation, show that the greatest deviations did not amount to more, and were almost always less than $\frac{1}{40}$th of the ordinates of the curve which represents them. And as, for experiments on hydraulic motive powers, such an approximation is quite sufficient, we have been able, in the ulterior calculations of the supply or delivery of water, to adopt the values of the coefficient of the supply or delivery deduced from this very curve.

We wish it to be observed that, in our experiments, the charges on the summit of the orifices having been comprised between 0·050 m. and 0·180 m. at farthest, and that this dimension, agreeably to the experiments of Messrs. Poncelet and Lesbros, producing an influence, at most, of only $\frac{1}{75}$, the variation of the coefficients has scarcely depended on any thing except the height of the orifices.

We have therefore been enabled, in accordance with this remark, to seek to compare the values of the coefficient of the supply or delivery which we have found, with those which have been determined for equal heights of orifices of 0·20 m. in width, by Messrs. Poncelet and Lesbros, and we have thus formed the following table :—

Nature of the Orifices.	Values of the coefficient of the theoretical supply or delivery for height of orifices of		
	0·20 m.	0·10 m.	0·05 m.
Orifice of 0·200 m. wide, .	0·592 m.	0·611 m.	0·630 m.
" 1·496. "	0·675 m.	0·679 m.	0·727 m.
Increase owing to the augmentation of width, .	0·083 m.	0 06 .	0·097 m.
Or .	·100 m.	·10 .	·100 m.
	8·130	10·000	7·530

It is seen that the width of our orifice appears to have had a considerable influence on the supply or delivery, and that the increase resulting from it for this supply or delivery has varied, in the cases in question, from $\frac{1}{75}$ to $\frac{1}{10}$.

These results prove how necessary it was to verify beforehand the exactness of the formula to be made use of for the measurement of the supply or delivery of water, since differences of this kind might result from it.

We will moreover observe that these results, giving amounts of supply or delivery much greater than might have been calculated agreeably to the rules generally admitted, the useful effects obtained from the motive powers studied in the experiments of which we have to give an account, will be diminished in the same proportion, and that, in this point of view, our results will be less favourable to them than if we had been content to follow the ordinary rules.

INTERNAL TEMPERATURE OF THE EARTH.

(*From Humboldt's Cosmos.*)

The figure of the earth, and the degree of solidity or density which it possesses, stand in intimate connection with the forces which animate our globe, in so far, namely, as these forces are not excited or awakened from without by our planetary position opposite to a self-luminous central body. The oblateness, a consequence of the operation of the centrifugal force upon a rotating mass, reveals the pristine or former state of fluidity of our planet. On the setting or solidification of this fluid, which we are accustomed to conjecture as existing in the shape of a vaporiform matter, originally heated to a very high temperature, an enormous amount of latent caloric became free. If the process of consolidation began in the way Fourier will have it, by radiation from the surface into celestial space, the parts of the earth which are situated towards the centre must still be hot and molten. While, after long radiation of the heat of the central parts towards the surface, a state of stability in the temperature of the earth is finally attained, it is at the same time assumed that, with an increase in depth, there will also be a regular progressive increase of temperature. The temperature of the water which flows from bores of great depth into the bowels of the earth (Artesian wells), immediate experiments on the temperature of the rocks in mines, above all, however, the volcanic activity of the earth, in other words, the discharge of molten mineral streams through fissures in the surface, bear testimony in the most incontestible manner to this increase of temperature in the upper strata of the earth at considerable depths. From conclusions which, it is true, are only founded on analogy, it is more than probable that the temperature goes on increasing in a still greater degree towards the centre.

The conclusions which have been presented to us by an ingenious, and, for this class of inquiries, singularly perfect analytical calculus, on the motion of heat in homogeneous metallic spheroids,* can only be applied, with many precautions, to the actual constitution of our planet, in consequence of our ignorance of the matter of which the earth is composed, of the various capacities for heat and powers of conduction inherent in the superimposed masses, and of the chemical transformations which solid and fluid bodies undergo under enormous pressures. Most difficult of all, for our powers of comprehension, is the conception of the boundary line betwixt the fluid mass of the interior and the concrete mineral species of the outer crust of the earth, of the gradual increase of solidity in the strata, and the state of tenacious semi-fluidity of earthy matters, to which the known laws of hydraulics can only apply under considerable modifications. The sun and moon, which keep the ocean in a state of alternate ebb and flow, act in all likelihood even down to these depths. Beneath a vault of already consolidated mineral strata, periodical rises and falls of a molten mass may, indeed, be readily enough conceived as taking place, and occasioning inequalities in the pressure exerted against the vault. The amount and the influence of such oscillations can, however, be but small; and if the relative position of the attracting heavenly bodies must here also produce spring tides, it is still certain that the concussions of the earth's surface which take place, are not to be ascribed to these, but to other more powerful internal forces.

* Poisson has developed an hypothesis totally different from the view advocated by Fourier (Theorie. analyt. de la Chaleur). He denies the present fluid state of the centre of the earth; he believes "that in cooling by radiation to the medium surrounding the earth, the parts first consolidated on the surface sunk downwards, and that by a double upward and downward current, the great inequality was lessened which would have taken place in a solid body cooling from the surface." The great geometrician thinks it more probable that the consolidation commenced in the parts lying nearer to the centre; "the phenomenon of the increase of heat with the depth does not extend to the whole mass of the earth, and is a mere consequence of the motion of our planet in universal space, the several parts of which, by reason of their steller heat (chaleur stellaire) have very different temperatures." The heat of the water of our Artisian wells, according to Poisson, is therefore heat which has penetrated the body of the earth from without; the earth may be viewed as we should a mass of rock transported from the equator to the pole in so short a time, that it could not cool completely. The increase of temperature in this block would not extend completely to its centre. The physical doubts which may reasonably be raised against this extraordinary cosmical hypothesis (an hypothesis which ascribes to heavenly space what must rather belong to matter in its first transition from the gaseous to the solid state), may be found collected in Poggendorff's Annalen, Bd. xxxix. s. 93—100.

There are groups of phenomena, the existence of which it is still useful to adduce in illustration of the universality of the attractive influences of the sun and moon upon the external and internal life of the globe, however little we may feel ourselves in a condition to determine numerically their amount.

From experiments on Artesian wells, which agree pretty closely, the temperature of the upper crust of the earth appears, on an average, to increase 1° of the centigrade thermometer for each 92 Paris feet in perpendicular depth.* Did this increase go on in arithmetical progression, then, as I have already had occasion to observe,† would a granitic stratum at the depth of $5\frac{2}{10}$ geographical miles‡ (from four to five times the depth of the highest peak in Himalaya range) be in a molten state.

In the body of the earth there are three kinds of motion of heat to be distinguished: the first is periodical, and, according to the position of the sun and the season of the year, alters the temperature of the earth's strata according as the heat penetrates from above downwards, or as it passes in the same way from below upwards. The second kind of motion is likewise an effect of the sun, and is of extraordinary slowness: part of the heat which has penetrated the equatorial regions is propagated along the interior of the crust of the earth towards the poles, and there escapes into the atmosphere and distant space. The third kind of motion is the slowest of all: it consists in the secular cooling of the body of the earth, in the dissipation of the small amount of the primitive heat of the planet which at the present time is still given off from its surface. This loss which the central heat suffers was very considerable at the epochs of the oldest revolutions of the globe; since the commencement of the historical period, however, it is scarcely mensurable by our instruments. The surface of the earth, from the foregoing view, is intermediate between the red heat of the interior strata, and the temperature of space, which is probably below the congealing point of mercury.

The periodical variations of temperature which the altitude of the sun and the meteorological processes of the atmosphere occasion, are propagated in the interior of the earth, but only to very small depths. This slow conduction of heat by the ground, however, lessens the loss of warmth in the winter, and is favourable to deeply-rooted trees. Points which lie at different depths in a vertical line come to the maximum and minimum of the communicated temperature in very different times. The more distant they are from the surface, the smaller are the differences of these extremes. On the continent of Europe, between the parallels of 48° and 52°, the stratum of invariable temperature occurs at from 55 to 60 feet deep; even at half this depth the oscillations of the thermometer, in consequence of the influence of the seasons, scarcely amount to half a degree. In tropical climates, on the contrary, the stratum of invariable temperature is met with at no more than a foot below the surface; and this fact has been used by Boussingault, in an able manner, as a convenient and, in his opinion, accurate way of determining the mean temperature of the air of a place. This mean temperature of the air at a determinate point, or in a group of points of the surface lying near to one another, is, in a certain measure, the fundamental element of the climatic relations, and also of the relations in reference to civilization of a country; but the mean temperature of the whole surface is very different from that of the earth itself. The oft-repeated questions, whether, in the course of centuries, this has suffered any considerable change?—whether the climate of a country has become deteriorated?—whether the winters have not become milder, and the summers in the same proportion colder?—can only be decided by the thermometer; and the discovery of this instrument scarcely dates three half-centuries back? its rational application no more than about 120 years. The nature and novelty of the means, therefore, prescribe very narrow bounds to inquiries into the temperature of the air. It is quite otherwise with the solution of the great problem of the internal heat of the whole globe. In the same way as from the unaltered rate of a pendulum we can conclude on the unchanged preservation of its temperature, so does the unaltered velocity of rotation of the earth on its axis inform us of the degree of stability of its mean temperature. This perception of the relations between the length of the day and the earth's temperature, is one of the most brilliant applications of a long knowledge of the heavenly motions to the thermal condition of our planet. The velocity of rotation of the earth, to wit, depends on its volume: precisely as the axis of rotation of the mass that was cooling gradually by radiation would become shorter, so through diminution in temperature must the velocity of rotation be increased, and the length of the day be abridged. Now, by a comparison of the secular inequalities of the moon's motions with the eclipses that have been observed in the more ancient times, it appears that since the age of Hipparchus, for full 2000 years, therefore the length of the day has not varied by the one-hundredth part of a second. From this, again, and within the utmost limits of the decrease* the mean temperature of the body of the earth is discovered not to have altered, in the course of 2000 years, by the $\frac{1}{170}$th part of a thermometrical degree.

This invariableness of form farther implies great invariabilty in the distribution of density in the interior of the earth. The translatory movements effected by the eruptions of our present volcanoes, the outbursts of ferruginous lavas, and the filling up of empty chasms and hollows with dense masses of rock, are therefore to be regarded as mere superficial phenomena, as peculiarities of parts of the earth's crust, which, in point of magnitude, when contrasted with the semi-diameter of the earth, are utterly insignificant.

The internal heat of the planet, in its course and distribution, I have described almost exclusively from the results and beautiful experiments of Fourier. Poisson, however, doubts the uninterrupted increase of the terrestrial heat from the surface to the centre. He believes that all the heat has penetrated from without inwards, and that the temperature of the interior of the earth depends on the very high or very low temperature of the universal space through which the solar system has moved. This hypothesis, devised by one of the most profound mathematicians of the age, has satisfied himself only; it has met with little countenance from other natural philosophers and geologists.

* The degree of the centigrade thermometer = 1·8° of Fahrenheit. The Parisian foot = $1\frac{1}{15}$ Eng. ft. very nearly.

† The increase in temperature is found in the Puits de Greneille. from 98·4 feet; in the bore of New-Salzwerk, Minden, almost 91 feet; at Pregny, Geneva, also 91 feet, although there the outlet is 1510 feet above the level of the sea. This agreement of results, from bores that are severally 1683, 2094, and 680 feet in absolute depth, by a method first suggested in 1821 by Arago (Annuaire, 1835, p. 234), is very striking. The two points of the earth at a short perpendicular distance from one another, whose annual temperature is ascertained with the greatest precision, are probably the external atmosphere of the Observatory of Paris and of the cellar under the Observatory. The former is 10°·822, the latter 11°·834 C.; difference 1°·012 C. for 86 feet of depth (Poisson, Theorie, &c., p. 415 and 462). In the course of the last 17 years, from causes which have not been ascertained, the thermometer of the *Caves* has risen 0°·220 C. If the penetration of waters from lateral channels into the main bore of Artesian wells produces some disturbance, it must be admitted that in reference to mines there are many more perturbing causes at work, and that interfere with the accuracy of conclusions in reference to their temperature at different depths. The general result of Reich's great work on the temperature of the mines of the Saxon Erzgebirge is the somewhat slow increase of 1° C. for 128½ feet of descent. Yet Phillips (Poggend. Ann. B. 34, S. 191), in a shaft of the Monkwearmouth coal-pit, found an increase of 1° C. for $99\frac{6}{10}$ feet of descent, exactly what Arago found in the Puits de Grenelle.

‡ That is German miles of 15 to a degree of the equator, and consequently each = to 4 Eng. Geo. miles of 60 to a degree, or to 4·603 statute miles of 69·038 to a degree of the equator.

FINLAY'S IMPROVEMENTS IN GAS LAMPS.

The very general introduction of gas light to dwelling-houses, which has taken place within the last thirty years, has had the effect of giving a considerable impulse to improvement in the construction of the apparatus by which it is applied, as a natural consequence of its more prominent position and the field for various adaptations which has been thus opened up for it. The present improvement by Mr Finlay, of Glasgow, refers to the particular arrangement of lamps which require to be raised or lowered for the purposes of lighting, or to suit the varying exigencies of the rooms to which they are applied. It consists in the substitution of the pressure of the atmosphere as a support for the lamp and its appendages, in place of the counterweights and hydraulic joint as ordinarily applied. The construction of the working portion of the barrel of the lamp will be readily understood from the annexed wood-cuts, which are drawn to a scale of one-half the original size.

* It is to be observed that the fraction $\frac{1}{170}$ of a centigrade degree of mercurial thermometer, which is given in text as the limit of stability of the heat of the earth since Hipparchus's time, rests on the assumption that the dilitation of the meterials of which the body of the earth consists is the same as that of glass = $\frac{1}{100000}$ for 1° C. of heat.

Fig. 1, is a view of the barrel of the lamp, partially in section; and fig. 2, is an external view of the supporting rod with its vacuum piston. *a*, is a tubular rod attached to the ceiling or other support of the lamp, and provided with a piston, *k*, at its lower extremity. *c c*, is the barrel of the lamp, which is bored to fit exactly to the piston, *k*, over which it is arranged to slide. *d*, is a screwed projection attached to the foot of the barrel, to which the lustres are attached; at this point also is attached, concentric with the external barrel, the gas tube, *e e*, which passes, air-tight, through the centre of the piston, and conveys the gas from the pipes above the barrel to the lustres.

Fig. 2.

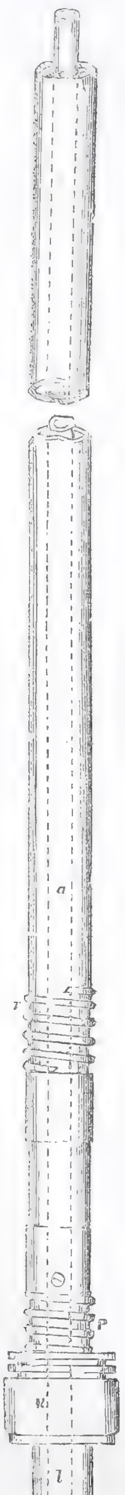
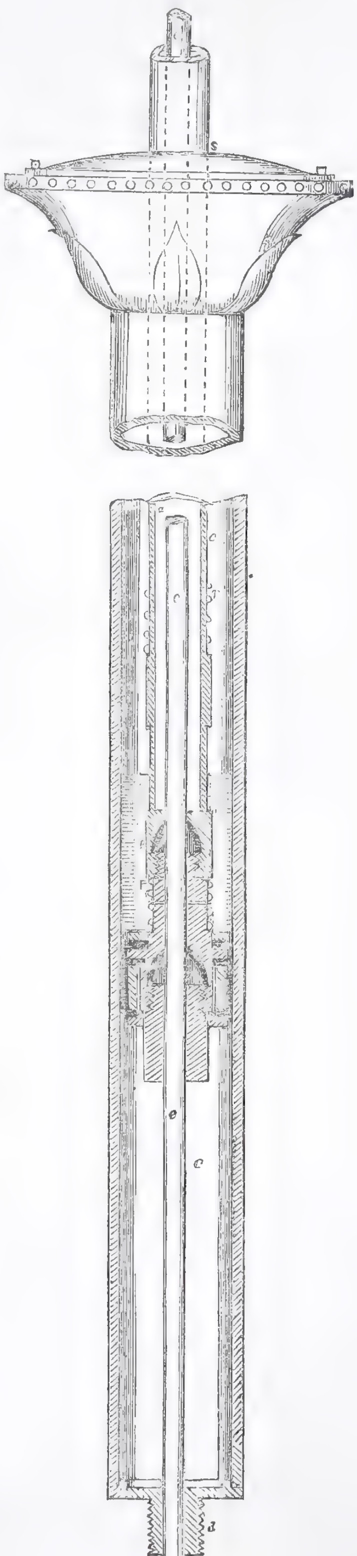


Fig. 1.



To put this apparatus in action, the barrel of the lamp is raised upwards until the piston, *k*, arrives at the bottom. A quantity of oil (as shown at *f*) is now poured into the barrel above the piston, in order to assist in keeping it tight. The barrel and lustres are now drawn down again and set to the required height, the vacuum thus occasioned beneath the piston being sufficient to support the whole apparatus; in this way it may be moved upwards or downwards at pleasure to suit the height required. The internal diameter of the barrel in the present instance is $1\frac{1}{8}$th inches; the atmospheric pressure produced on which, by the vacuum beneath the piston, is equivalent to 12 pounds—to which weight, the barrel and lustres must be brought by means of modifying the weight of different portions to suit it, any greater weight of lamp being provided with a working barrel of greater diameter.

The piston *k*, the peculiar construction of which we have now to explain, is composed, in the first place, of a hollow cup, cast on the end of the tubular rod, *a*; to this is screwed the main portion of the piston, *k*, the upper end of which presses upon the leather packing of the leather cup, so as to form an air-tight joint on the rod *e*. The leather packing ring, *k*, of the piston is held in its place by the screwed piece *l*, which at the same time acts upon the packing in the lower cup, so as to keep it tight. In raising the external barrel of the lamp, it is evident that whatever amount of air or oil may have gathered beneath the piston must be expelled previous to forming the vacuum. To accomplish this, the piston is provided with a circular leather valve, which covers the holes in the piston, communicating with the portion of the barrel below the piston. This valve is kept down in its seat by means of the helical spring, *p*, which presses on the brass ring, above the leather valve. Thus when the barrel is raised, the compressed air or oil beneath the piston raises this valve and escapes through the holes, *o o*, the air being prevented from re-entering, by the pressure of the spring above the valve. *r*. is a second helical spring encircling the tubular rod *a*, and resting upon a projection cast upon it; its intended use being to prevent the shock which no doubt would otherwise be occasioned by the piston coming in contact with the plate, *s*, when the barrel of the lamp is drawn down suddenly. There are two holes drilled in the body of the piston for the purpose of supplying the leathers of the cups with oil as a lubricator.

It will be observed, that although our illustrations of this very ingenious idea relate only to gas lamps, yet it is obvious that its application may be extended to lamps of all kinds. In such cases, the place of the tubular rod, *a*, would be supplied by a solid rod to act merely as a support for the lamp.

MACHINE FOR DOUBLE SEAMING TIN WARE.

Mr. George Moore, of Philadelphia, lately submitted a machine for this purpose, to the members of the Franklin Institute, who have signified their high opinion of it as an instrument of great value to the tin-plate worker. We copy the following description and engraving of it in the patentee's words, from the Franklin Journal:—I proceed to describe the working machinery, noticing first the two arbors, *a* and *b*, which are connected by cog wheels, and turned by the crank, *c*. Two heads, *d* and *e*, are affixed to the ends of these arbors, and between these heads the double seaming is performed. A pan, *p*, is represented in dotted lines, as placed over the head, *d*, on the lower arbor, so as to bring the edge which is to be seamed down between the head, *e*, and a small roller, *f*, hereafter described. The shape of the head, *e*, should be carefully noticed. This head consists of a flanch, 1, projecting from a cylindrical surface, 2, similar to some other machines now in use; this cylindrical surface is terminated by a shoulder, 3, that connects with a conical moulding, 4. The bevel surface of the head, *e*, bears first upon the edge of the pan, which is sustained by the head, *d*, the shoulder, 3, above named, coming against the bottom, and the edge is forced to yield to the bevel of the head, *e*, as this is screwed down upon it by means of the screw, *g*, and should any part of the edge be inclined to slip out towards the top of the pan, (as this edge is always composed of three thicknesses), it is prevented from so doing by the little roller, *f*, attached to the collar, *k*, that surrounds the arbor, *b*, near the head.

At this stage of the operation, the crank, *c*, is turned, the pan

L SCREEN.

Fig. 3.

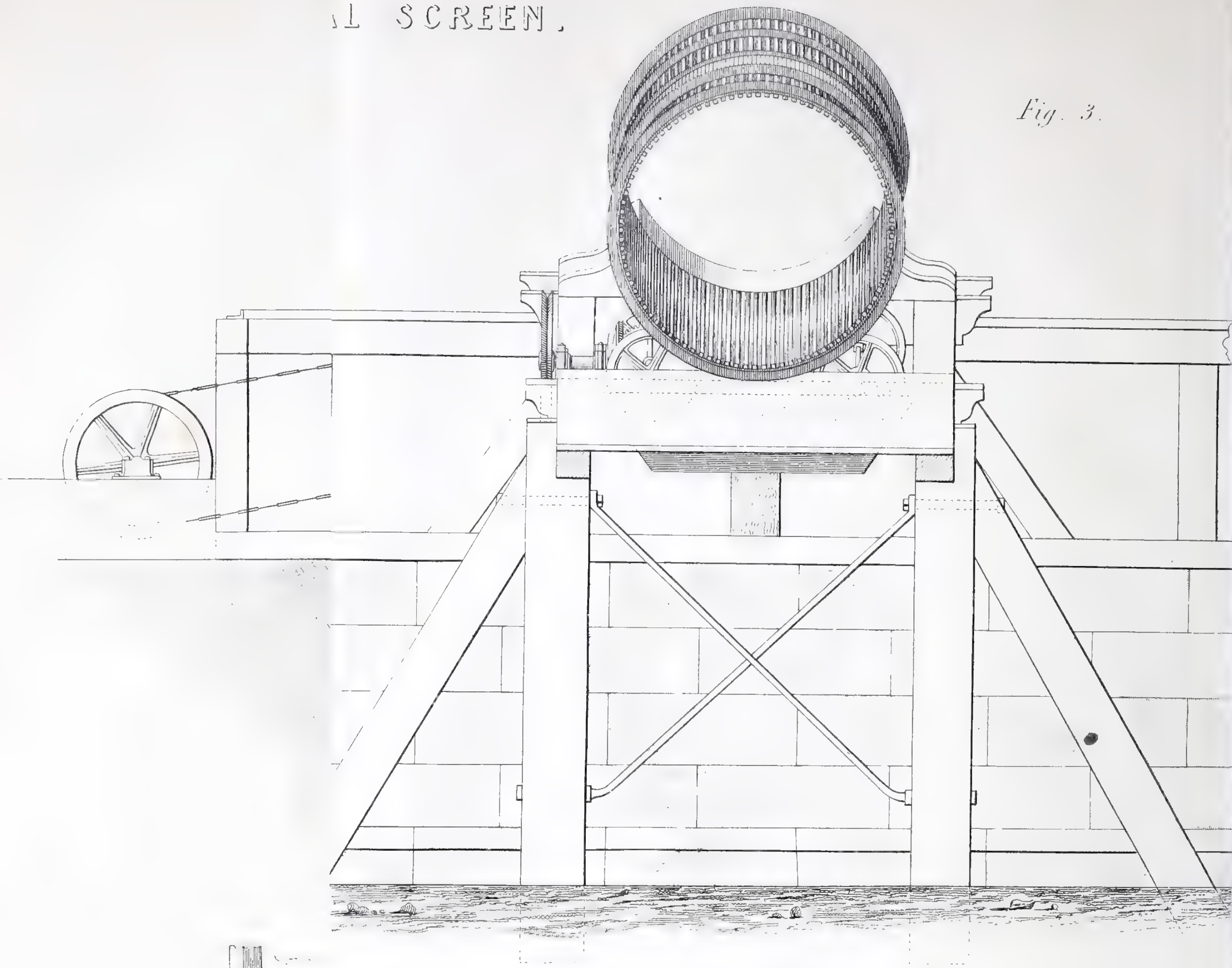
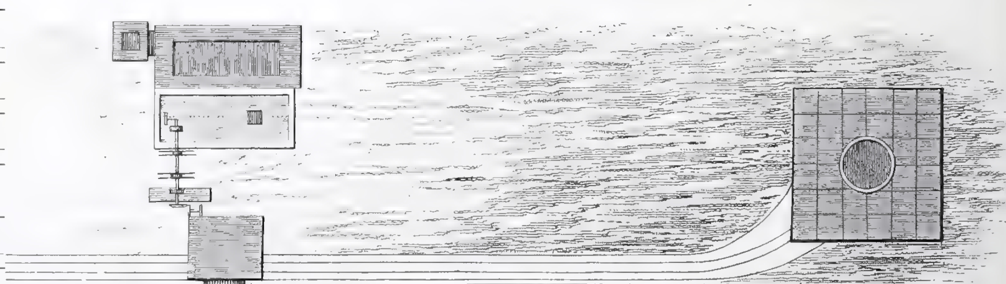


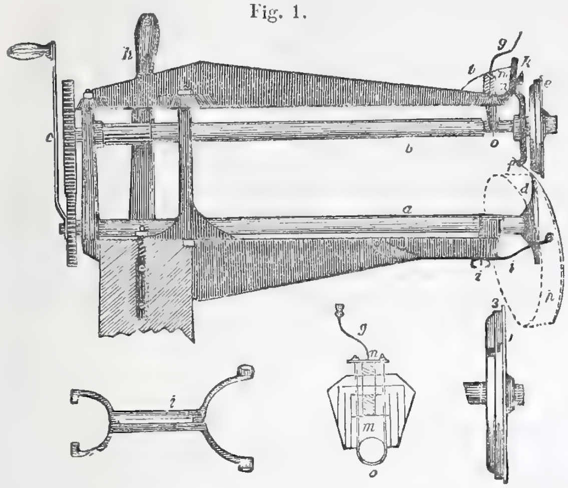
Fig. 4.



Geo. Aikman Sc.

revolves in the machine, and the edge is turned down as far as the bevel part, 4, of *e*, will turn it, while the shoulder, 3, prevents the edge of the pan from bending too far down towards the centre; after this, the head, *e*, must be raised up a little by turning the screw, *g*, attached to the box, (in which the arbor, *b*, runs), and then the lever, *h*, is brought into use, to move the arbor, *b*, inwards, by which the cylindrical part, 2, of the head, *e*, which is

Fig. 1.



parallel with the outer surface of the head, *d*, is brought over the same, and then screwed downwards towards it by the screw, *g*, when, by again turning the crank, the work is completed. The outside shoulder, 1, of the head, *e*, keeps the bottom of the pan close against the head, *d*. The lever, *h*, passes through an aperture in the frame, where it has room to be moved back and forth, and places are fitted to receive it when so moved, into which it is thrown by a spring, or by its own elasticity. It also passes between two shoulders on the arbor, *b*, and its lower end is connected to the frame by a pivot. Its use has already been explained. *i*, is a sliding guage for the purpose of holding in proper position flaring articles, such as the pan represented in the drawing, where the bottom needs to be thrown out from a perpendicular with the arbors, in order to bring the body parallel with them. This guage consists of a shank that is attached by the screw, *j*, to the frame, and is terminated by heads branching out for the bottom of the pan to rest against, upon the inside. This is found to be indispensable when the work is much flaring. The heads of this guage are provided with soft or smooth surfaces, to prevent them rubbing the tin so as to mar or injure it. When it is not desirable to use the guage, the work will rest against the head, *d*, which is faced nearly to the edge with leather, although other materials may be used, to prevent its rubbing the tin.

The piece, *k*, is a collar with a lever attached thereto; the collar part of it is fitted upon the arbor, *b*, allowing the arbor to turn freely in it, while the upper end passes through a loop, *m*, in the frame, to keep it in an upright position, and below the collar, this lever passes through the little roller, *f*. The only use of the loop, *m*, is to bring the roller, *f*, to bear properly upon the work; and to secure this the better, the lever, *k*, is made crooked at the top, so that, by pressing it down, this part of it is brought towards the frame, and consequently the roller, *f*, is moved up closer towards *e*, and *vice versa*.

A spring, *l*, is applied to throw *k* back, as it rises up, to make it easy to get the work properly into the machine.

The screw, *g*, is so connected with the arbor, *b*, by means of a bow and yoke, that both are raised or lowered at pleasure.

WALKER'S IMPROVED REVOLVING COAL SCREEN.

We have given in a Plate a series of detailed views of an extremely ingenious coal screen or riddle, invented by Mr. Walker, of St. Helens, Lancashire. The ordinary mode of separating the different sizes of coal by means of hand riddles, is well known to involve numberless disadvantages, and to add considerably to the expense of this fuel.

Perhaps one of the greatest drawbacks attendant upon the ordinary plan, where the coal is riddled below, is the fact of an immense quantity of the small coal being left in the workings by the pitmen, whose object it is to send as much large coal to the surface as possible, their wages being of course regulated in a considerable degree by the value of the material. In using Mr. Walker's machine, however, the whole of the coal is at once sent up, so that the proprietor is not inconvenienced by his workings getting choked, neither does he lose the great amount of small coal left behind, which in some districts may be taken as about 15 per cent. of the whole.

The various views in Plate IX. will render the machine easily understood.

Fig. 1. is a ground plan of the framing, &c. with the screen removed, showing the gearing used in driving the apparatus.

Fig. 2. is a side elevation of the screen, with the delivering channel and waggons for receiving the coal and slack. Fig. 3. is a front elevation of the delivering end of the machine, and fig. 4. is a plan of the pit-brow on a small scale, showing the application of the machine to two pits.

The cylindrical riddle or screen A, is constructed of five wrought iron hoops, within which are rivetted, longitudinally and parallel to each other, a series of bars of wrought iron, sufficiently far apart to permit slack of the required size to pass through. Two of the hoops A, A, are turned perfectly true, and provided with flanges in order to fit to the four friction wheels B, B, the revolution of which, turns the riddle. These wheels are keyed on two horizontal shafts H, H, placed in a direction parallel with the axis of the riddle, and at a sufficient distance from each other to retain it steadily during the working. These shafts are coupled together by a pair of rods C, C, so as to allow of being driven by one set of gearing. Motion is communicated to the four friction wheels, by means of the arrangement D, D, connecting them with the engine shaft; E, is the receiving hopper, into which the coals are discharged, in passing them through the riddle, from whence they are shot down the inclined channel F, into the coal waggon on the front line of rails, the slack passing through the bars of the riddle into the hopper G, whence it is conducted into the waggon on the back line of rails.

Fig. 4. explains the application of the machine to two contiguous pits, being an exact representation of the arrangement at Messrs Speakman and Caldwell's colliery, St. Helens, now in constant operation.

The winding engine is placed as marked at H, so as to command both the pits P, P; from the pulley shaft of the engine, motion is given to the riddle A, as seen in the large view, fig. 1.

K, K, are tramways from the pits, for conveying the coal to the riddle. Each pit is provided with a cast iron stage L, raised about three feet higher than the level of the pit brow; the tramways lead direct to these stages, which, by their elevation facilitate materially, the removal of the coal. This arrangement of course depends greatly upon the peculiar locality in which the machine is placed; the one before us, however, has the advantage of great simplicity and convenience. The construction of the riddle and machinery throughout, is remarkable for the simple means employed for the end in view, and carries with it the great recommendations of facility of erection and application. Wherever machinery can possibly be substituted for manual labour, it is evident that nothing can be more desirable, as tending to the moral improvement of the great bulk of the human race.

DISCOVERY OF MECONIC ACID, AND A NEW ALKALINE BASE (CYTISUINE) IN THE BARK OF THE LABURNUM.

BY MR. R. SMITH, CHEMIST, BLACKFORD.

Meconic acid is generally understood by chemists to exist only in opium, having been discovered by Seguin in 1804, who gave it its present name from μηκων, poppy. The author has now succeeded in producing it from the bark of the Laburnum, by a very simple process. The bark is first cut into small fragments, and is then immersed in hot water, in which it is allowed to stand for a day or two in a warm situation, or it may be digested with a gentle heat for three or four hours; the liquid is then filtered, and a solution of the diacetate of lead is added, until all precipitation has ceased. The precipitate is then washed upon the filter until the water passes from it in a colourless state; it is then diffused in

water, and a stream of sulphuretted hydrogen gas being passed through it, sulphuret of lead is precipitated. The solution is again filtered in order to collect the sulphuret of lead, which leaves behind it a solution of meconic acid. Its presence being detected by adding a few drops of a solution of persulphate of iron, which produces the deep red colour, characteristic of the acid. By evaporation, the filtered liquor will deposit fine crystals of the pure acid.

The liquid passed through the filter during the collection of the precipitate, formed by the diacetate of lead, is evaporated to the fourth part of its bulk, and a quantity of alcohol added to it. The alkaline principle then combines with the alcohol, and a gum is precipitated; the whole is then filtered in order to separate this gum from the alcoholic mixture. If the gum powder is then dissolved in water, and permitted to stand for several days, the powder will be gradually deposited, forming a hard gum, semi-transparent, and of a reddish brown tint.

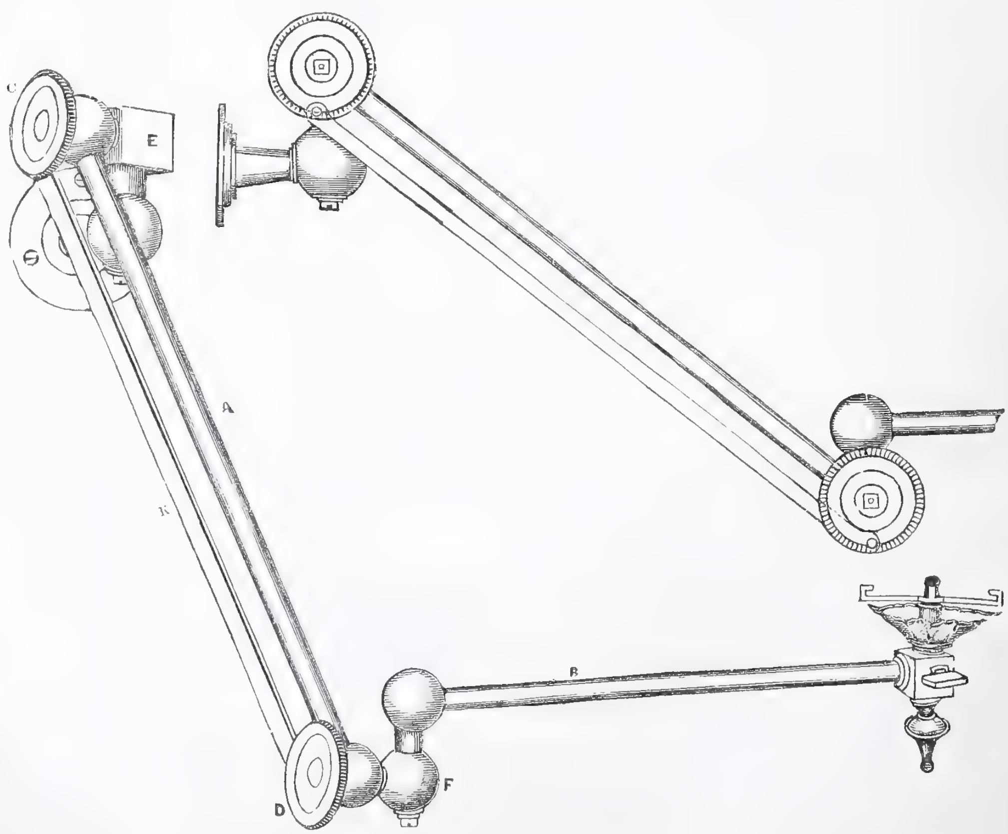
If an excess of lime water is added, a whiteish brown precipitate is afforded, to which the author has given the name of cytisuine, from the plant (Cytisus Laburnum) producing it; it is soluble in acids, alcohol, and ether; the alcoholic solution changes red litmus test paper to a blue colour, and turmeric, brown. It combines with nitric, sulphuric, muriatic and acetic acids, forming salts. A solution of the muriatic or acetic acid produces a purplish blue with a solution of the sesquichloride of iron, as in the case of salts of morphia; it is not changed to a red colour by nitric acid, like the salts of strychnia and morphia.

The influence of this base upon the animal economy remains yet to be seen; it is however highly probable that its effects will resemble those of the plant, which is highly poisonous, producing great pain in the stomach, inflammation, intoxication, vomiting, and death. In cases of examination of the contents of the stomach when laudanum has been taken as a poison, Dr Christison recommends acidulation with acetic acid; then boiling to the consistency of a syrup, and lastly boiling with strong alcohol, any coagulum formed on the surface to be broken down. The product of evaporation of this solution is then to be dissolved in distilled water and filtered. Meconic acid and morphia may be detected in the solution by the usual tests. Nearly the same results would be produced in cases where Laburnum bark had been taken; this is a point of considerable importance to the investigator, as in testing for meconic acid, laburnum and laudanum would give results almost identical, while the cytisuine of the laburnum when treated with the sesquichloride of iron, would produce the same colour as morphia. Nitric acid however, gives a deep red when treated with morphia, whilst it only tinges a solution of cytisuine, yellow. The test of nitric acid cannot be depended upon for giving accurate results, as strychnia, some of the salts of potassa, resin, and other de-oxidating agents produce the same effects.

CHISHOLM'S PARALLEL GAS BRACKET.

This is an attempt to remedy an evil which is inseparably attached to the common double-jointed bracket, namely, the twisting to which the light bearer is subjected in altering its height, so that the glass shade of the light is perpetually in danger of being thrown off its seat, or of being cracked by the contact of the flame.

Fig. 1 of our illustrations represents a perspective view of the bracket. Fig. 2 is a plain side view.



The upper and lower tubes of the bracket, A and B, are constructed in the usual manner, but an addition is made to the joints of each, in the shape of two discs, C and D, which are fixed to the plugs of the shells, E and F, so as to revolve with them. The thin metal bar, K, is jointed to each of the discs, and the result of the arrangement is, that in whatever direction the upper tube is moved, the lower one, bearing the burner, is preserved in a horizontal position, without subjecting it to any twist whatever. The extreme position in which we have here shown the upper tube explains the amount of motion of which it is capable, without disturbing the parallelism of its lower neighbour.

A GLANCE AT THE STRUCTURE OF THE GLOBE.

An examination of the cosmogonies of the Brahmins, the Chinese, the Persians, of the Edda, the Egyptians, and the Jews, will show that they have this in common, namely, the assertion that a very long space of time intervened between the first elementary form of the earth and its present state; that the firm ground emerged from the fluid elements, and that the crust of the globe has undergone many vicissitudes, especially in the conflict of fire with water. Lastly, this thought stands written in them all with illuminated letters—that the creation of all things was accompanied by the intermixture of two opposite qualities, like affirmative and negative, like light and darkness, or attraction and repulsion, both of which are influences from an almighty, eternal, and uncreated spirit, superior to time and space. In the polar opposition we see this fundamental affection of matter, the creative power which brings things into the region of perception. The same thing is meant by the Chinese cosmogony, when it speaks of Yang and Yu, affirmative and negative, and by the oriental when it speaks of light and darkness. Number and form is its symbol. The relations of number in the greatest variety of combinations run through all nature, and every thing that is, or will be, necessarily conforms itself to this law. Mathematical science is applicable to the whole universe, and every thing conprehended therein. All numerical relations are intimately connected with polar opposition, which is displayed in magnetism, as north and south in electricity, as plus and minus in chemistry, as attraction and repulsion in crystallography; first, as regards the symmetrical form, next the electrical condition of the crystal. And all these contrasted forces are in subordination to that universal one of gravitation, and that which we must look upon as the highest polar contrast of nature. It is the great polar streams of force which set all the inert fluid and aerial masses of the earth in everlasting, we may almost say, in living motion. Every one gives something to another, every one receives something from another, each one has peculiar effects. In their active changes something speaks to us that reminds us of life, and we may in this point of view look upon them as the implements of the globe by which it performs its appointed duties and exhibits its peculiar qualities. For without air and water the ground would be a bare desert stony mass, and in many respects perhaps not unlike the moon. Its surface would be scarred and confused by deep rents, wrinkles, and depressions, by sharp and rugged groups of hills protruding in high chains in every direction. It was the moving water and the ever-restless air that first scared away deadly stillness from the earth, wrapt it in a green garment, filled the woods with choristers, and gave man a home.

It is highly probable that the increase of heat in the interior of the earth, as well as the increase of cold in the air, has a limit—that at a certain point below, there is a degree of heat that never changes, and that at a certain point above, there is one continuous degree of cold. Fourier and Svanberg have attempted to ascertain the temperature of the latter point from experiments of balloon voyagers. They fix the degree at 40° Centigrade, and think this is the temperature of the regions of space. Besides the proper heat of the earth, its surface is daily warmed by the sun's rays. The sun itself however appears to radiate no heat, and its light to be in fact in cold. According to the new theory, what we call a ray of the sun is an undulation of a matter called æther, spread throughout all space, and originating in the sun's atmosphere, which æther is of such rarity that it is not perceptible by human organs in any other way than by its effect on vision, and is of such elasticity that a particle oscillates several hundred billion times in one second. In tropical climates the greatest heat of the day is about 2 o'clock and reaches in the shade to 40° C. In the temperate zone the greatest heat is in winter about one o'clock; in summer between 2 and 3. In cold climates the cold will reach 40° C. In the polar regions where the temperature has depressions like what it experiences in North America and Siberia, the soil is frozen one hundred feet below the surface. Universally, heat decreases from the equator to the poles, but not everywhere in the same manner, and there are important differences. Lines drawn through places where there is an equal average temperature are called *isothermal* lines. They form very peculiar curves which parallel circles frequently cut through, and are not concentric with the geographical pole, but upon the northern half of the globe are concentric with two other points, of which one lies under 78° north latitude, a little north of the mouth of the Lena; the other somewhere about 76° N. L. upon a newly discovered island off North America. These two points are the poles of cold of the northern part of the globe. The Asiatic pole has a medium temperature of $13\frac{3}{4}$ R., and the American of $15\frac{3}{4}$ R. The pole on the southern portion of the earth is not yet known. Probably it does not coincide with the geographical pole. According to the calculation of Raemtz, the medium temperature of the north geographical pole should be $43\frac{1}{5}$ R., and of the opposite pole $9\frac{1}{15}$ R., and if this is correct it seems that the south pole is very much colder than the other.

Amongst the four planets nearest the sun the earth appears to be the only one that possesses a sea. This covering of water which envelopes more than two-thirds of the globe, receives an ellipsoid form from the revolution of the earth round its own axis. It endeavours to retain its equilibrium, and this equilibrium becomes destroyed; the weight at the equator being $\frac{1}{200}$th less than at the poles, and the masses of water are increased at the equator, and consequently deeper. Laplace has proved by calculation that the sea is no where more than 12 miles deep, and if we take into our reckoning the difference of the two diameters of the earth, 15 miles, the diameter of the equator, will be about 24 miles longer than the axis. The difference however, does not appear actually to be so great. The bottom of the sea in the Atlantic ocean, 690 miles south-west from St. Helena, was reached by a line of 14,556 feet, and it is highly probable that the mass of the sea under the equator is little more than three miles in depth, and consequently the ellipsoid form of the watery envelope would still more approach the spherical. The northern polar sea appears to have an average depth of 800 feet; but the south polar ocean is perhaps deeper than 12,000 feet. Internal seas have usually a trifling depth. The Baltic for example, has in its middle only an average depth of 180 to 240 feet, and the bottom of the German ocean, if the Atlantic fell 600 feet, would be laid dry, and a hilly surface would be exposed, something like the continent in the north of Germany, of which it would form a natural expansion. The Doggerbank, which extends for 354 miles from north to south into the sea, and another bank having for 110 English miles a north-westerly direction, would make important chains of hills. Thus man in his frail vessels floats on the flat surface of the water over hills and vales beneath, and only now and then is he conscious that he passes over some lofty mountain, seldom knowing that the depth beneath him frequently changes from several thousand feet to a few fathoms. If we take the medium depth to be 12,000 feet, we have a mass of water on the globe which it would take all the rivers of the earth 40,000 years to pour down if they continued to contribute the quantity they now do. What then is the Maranon, king of streams, mighty enough to have confounded his discoverer, and lead him to doubt whether he saw a river or an arm of the sea—what are all the streams, rivers and seas, which traverse all continents like veins, carrying with them the sap of earth through all lands, in

comparison with the ocean out of whose superfluity they are created, and who is ready again to receive them? What are the masses of any land we proudly call quarters of the globe, to that collection of waters which embraces them all like islands in its dark bosom?

All the planets of our system and the sun itself are surrounded by a gaseous envelope of more or less density. The rarer atmospheres are nearest the sun, and the denser ones furthest distant. Although this gaseous matter is 900 times lighter than water, yet it presses with a weight of $14\frac{1}{2}$ lbs. upon each square inch of the earth's surface. Its total weight is about one millionth part of the weight of the globe. Partaking of the globe's rotation it has an ellipsoid form in consequence of the greater heat, bulk and centrifugal force at the equator, and the longest diameter of this figure is that at the equator. According to the law propounded by Mariotte and Boyle, the density of the air is in direct proportion to the force of pressure, that is in whatever degree pressure is exerted, in the same degree the space which the confined air occupies, becomes less, so that if we apply a force four times greater than that by which its existing density is effected, the stratum of air takes up just one-fourth of its previous room. Hence it follows that the upper strata of air are rarer than those below. According to Mariotte the space occupied by the same quantity of air stands in inverse ratio to the compressing power or the spaces of two strata, of which one is subjected to a pressure of 4, and the other of 12, and are in proportion not as $4 : 12$, (that would be direct), but as $12 : 4 = 3 : 1$, that is, the first stratum occupies one-third more space than the last.

With reference to the inequalities of the earth's surface, the first question that occurs is as to the cause of the upheavements, depressions, and volcanic eruptions, which we see upon it. Thales, of Miletus, one of the seven wise men of Greece, was of opinion that the earth was a mass afloat in the ocean, and its disturbances appeared to him to be like the unsteadiness of a vessel upon the water. Anaximenes of Miletus (545 years before Christ), looked upon the earth as an antiquated building which shook now and then from sheer feebleness like a house where a beam snaps, or a ceiling gives way. His scholar Anaxagoras endeavoured to explain that the derangements of the earth were caused by lightning. Aristotle fancied the origin of these phenomena was in the nature of the atmosphere, its pressure and its susceptibility of being compressed by cold expanded by heat. Others have supposed an internal fire. Humboldt has the great merit of having first shown the widely spread connection of volcanic activity upon the earth. From the position and appearance of the volcanos of South America, which he visited from 1799 to 1804, his investigating eye perceived that all the fiery places of the earth had one common source, and that 187 points of communication existed between the reservoir of internal fire and the atmosphere. That these reservoirs were placed at a great depth below the surface was evident from their eruptions shattering at the same time, a large portion of the earth's crust, and the similarity of the phenomena at very distant places. There can be little doubt that steam is the cause of the greater part of volcanic outbreaks. When a quantity of water has been drained through into the interior, and has come into contact with the heated matter, a vast quantity of steam is generated, and its expansive force endeavours to effect an escape. An instance of the tremendous force called into existence by the sudden meeting of fire and water occurred in 1802 at the iron works of Colebrookdale. A waterspout broke over the place, and in a few minutes the stream rose seventeen feet and rushed into the smelting furnace, where there was 2000 cubic feet of iron ore in a molten state, and a terrible explosion ensued. Three times did a fiery column more than a hundred feet high arise into the air; the ore was scattered on every side, so that not a particle was left in the furnace; the neighbouring houses were seriously damaged, and a great heat was felt several hundred paces from the spot.

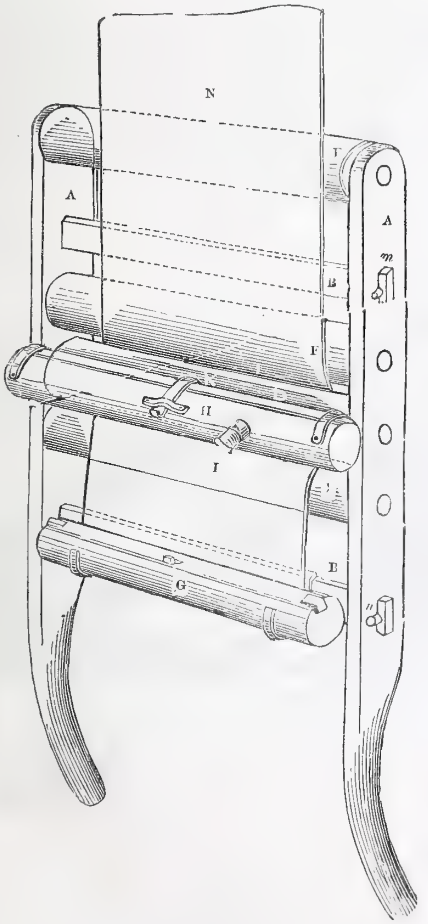
The expansive force of steam is in proportion to the temperature. At a temperature of 360° C., the pressure is equal to that of 15436 atmospheres. According to Parrot's calculation, steam at 1750° C. would lift lava sufficient to make 200000 trillions of fathoms. If then a collection of gas and steam vapour is subjected in subterranean passages to heat even of a much lower temperature than that we have been speaking of, it expands more and more until meeting with the molten matter beneath the crater of a volcano, an upheaving and explosion take place. Or if the steam is converted by heat into its constituent gases, and an explosive compound is formed, this gets kindled and a disturbance ensues, which is felt along the surface in convulsive shocks. The interior of the earth may be considered as a great natural laboratory where substances are fused, resolved into their constituent elements, rendered gaseous, formed into new combinations. and subjected to enormous pressure. In undergoing these processes no doubt a great quantity of electricity is generated, and hence probably are caused the thunderings which are often heard below, and the appearances of lightning which are sometimes seen in the craters of active volcanos. According to Ampère all the phenomena of the needle, and the magnetic streams that flow universally from N.N.W. to S.S.E., are explained, if we assume that electrical streams circulate in directions parallel with the magnetic equator. Those electrical currents have been found in the passages of mines. Ebel indeed went so far as to say that the earth is an immense generator of galvanism—that the parallel strata as they exhibit themselves in Alpine countries, grandly thrown into masses perpendicular to the horizon, are elements of the apparatus—and that galvanism is the primary cause of the great chemical operations and all the phenomena of the earth's interior. If geology as at present understood, bids us reject this idea, still so much ignorance exists and must exist as to the processes going on below, that it is impossible to say how much of it is false or true. This however we know, that the operations there carried on must be extremely complex, and nothing we at present know enables us to say which is the cause, and which the effect. Is heat or electricity the generator of movements there? Heat brings about it is true, chemical processes—but it is equally true that heat is caused by chemical process. Electricity also occasions revolutions and combinations; but these operations on the other hand evolve electricity.

It is a well known hypothesis that at a depth of from 40 to 60 miles the interior of the earth is in a state of fusion. This supposition however, has some difficulties to contend with; for in the first place it may be asked how it happens that this enormous heat does not only not reduce the crust to a fluid state, but allows snow and ice to settle upon it, and near the poles permits the earth to be frozen to a considerable depth below the surface. To meet this objection, it is said that our globe moves in space, which is very cold, and that a radiation of heat takes place to a degree which keeps the surface solid. Granting this to be so, yet we know that radiation has the effect of gradually reducing the whole mass of a heated body to a cold temperature, and could there be any heat remaining in the earth's interior after a lapse of thousands of years? To this it is answered that the bad conductors with which the earth is surrounded, air, water, loose mould have prevented a greater radiation, and consequently a more rapid decrease of temperature. Fourier has demonstrated by calculations that the yearly decrease of temperature is very slight; that in the course of 2000 years there has been no variation in the average temperature to a greater extent than $\frac{1}{30}$ th part of a degree. This result agrees with that at which Laplace arrived, namely, that since the time of Hipparchus (140 B. C.) there has not been a greater de-

crease of heat than $\frac{1}{200}$th part of a cent. degree. Hipparchus determined with wonderful accuracy the length of the year in days, hours, and parts of an hour, and his observations upon the earth's rotation in his time, have been transmitted to us by his scholar Ptolemy. Laplace has shown that the time of rotation has not varied the hundredth part of a second. But had the earth cooled only one degree (C.) it would have contracted, the diameter would have been made less, and then the time of rotation, and consequently the year would be less also, because if the moving power remain the same, the globe being of less size would rotate more quickly, and its course round the sun would have been performed in less time.

MACHINE FOR PAPERING WALLS.

This figure, which is a perspective elevation, represents a machine for papering the walls of rooms, for which a patent was granted to Henry F. Baker of Centerville, Wayne, Co. Indiana, U. S., on the first of November, 1854. A A are two side bars, and B B are two cross pieces framed in the said bars, and C D E and F are four rollers; G and H are two tin cylinders. Cylinder G, for holding the paper, and cylinder H,

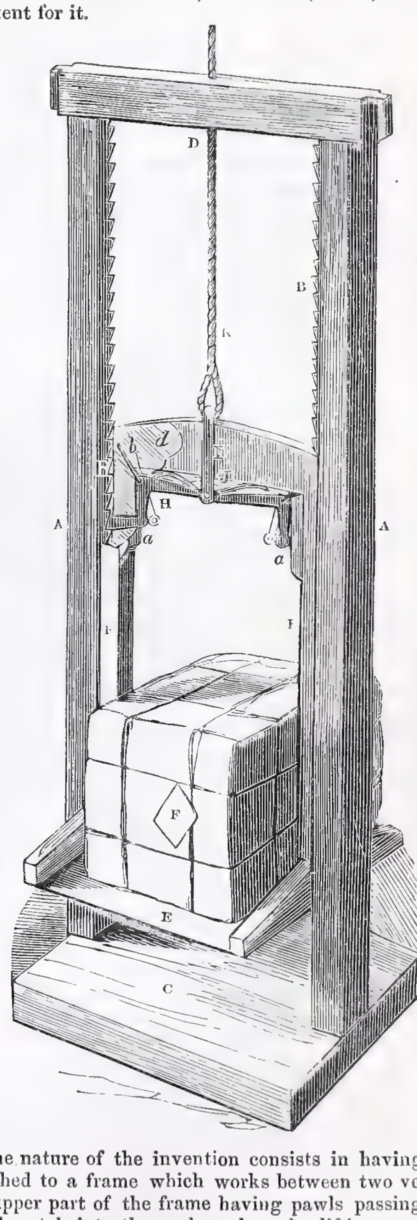


for holding the paste or sizing. Roller D is covered with sponge or sheepskin, or its equivalent, and roller F with gum elastic cloth, or its equivalent, for the purpose of pressing the paper to the uneven surfaces of the wall, and by that means press all the air from between the paper and the wall, and cause the paper to be laid on smoothly, nicely, and evenly, without the trouble of hand labour. Cylinder G has a lid to it, for the purpose of putting in the paper, and has also a small orifice in front to let the paper pass through. Cylinder H has a hole, I, in the top to put in the paste, and also an orifice in the bottom, next to roller D, with a slide, K, to let on and off the paste on to roller D. *m n* are two keys in the end of the cross pieces framed in the bars, for the purpose of taking the machine apart, when necessary to clean. It is readily perceived that the paper, N, placed in cylinder G, passes out of it over roller C, under D, and over roller E and F, against the wall to be papered; and that, when the paper is pressed and rolled on the wall, it will cause all four of the rollers to revolve and draw out the paste from cylinder H, and cause it to be spread upon the paper.

The patentee states that, by this machine, as much wall papering can be done by one hand in a given time, as four or five hands without it—sizing the paper at the same time.

OTIS' IMPROVED ELEVATOR.

The annexed figure is a perspective view of the Improved Elevator of Elisha G. Otis, of Yonkers, N. Y., who has secured a patent for it.



The nature of the invention consists in having a platform attached to a frame which works between two vertical racks, the upper part of the frame having pawls passing through it which catch into the racks, when the lifting power which is

applied to the frame is stopped or taken off. The pawls are attached to bent levers, which levers are connected to a rod to which the lifting rope or chain is secured.

A A represent two vertical posts, having racks, B B, secured to their inner sides. The lower ends of the posts may be secured to a suitable base, C, and their upper ends may be attached to a tie piece, D; E is a platform attached to the lower part of a rectangular frame, F, which frame works between the two racks, B B, the racks fitting in grooves in the outer surfaces of the side pieces of the frame. G G are pawls which are secured by pivots, *a*, to the lever ends of right-angled levers, H H, said levers having their fulcra at *b b*. The upper ends of these levers are secured by a pivot, *c*, to the lower end of a rod, I, which passes vertically through the centre of the top cross piece, *d*, of the frame, F. J is a spring which passes through the lower end of the rod, I, underneath the cross piece, *d*. The ends of this spring bear against the lower surface of the cross piece, K is a lifting rope secured to the upper end of the rod, I.

The weight or bale to be elevated is placed upon the platform, E, which of course is at the lower ends of the posts, A, and resting upon the base, C. The power is then applied to the rope, K, and the rod, I, is drawn upward, and the pawls, G G, in consequence of their attachment to the levers, H H, are withdrawn from the racks, B B, and the frame and platform ascend till the weight is elevated to the desired height. The lifting power then ceases, and the weight or article is taken off.

By the above improvement, the pawls are prevented from bearing against the racks during the upward movement of the frame, F, and much friction is obviated thereby; and if the rope should break, or be loosened from the driving shaft, or disconnected from the motive power accidentally, the platform will be sustained, and no injury or accident can possibly occur, as the weight is prevented from falling.

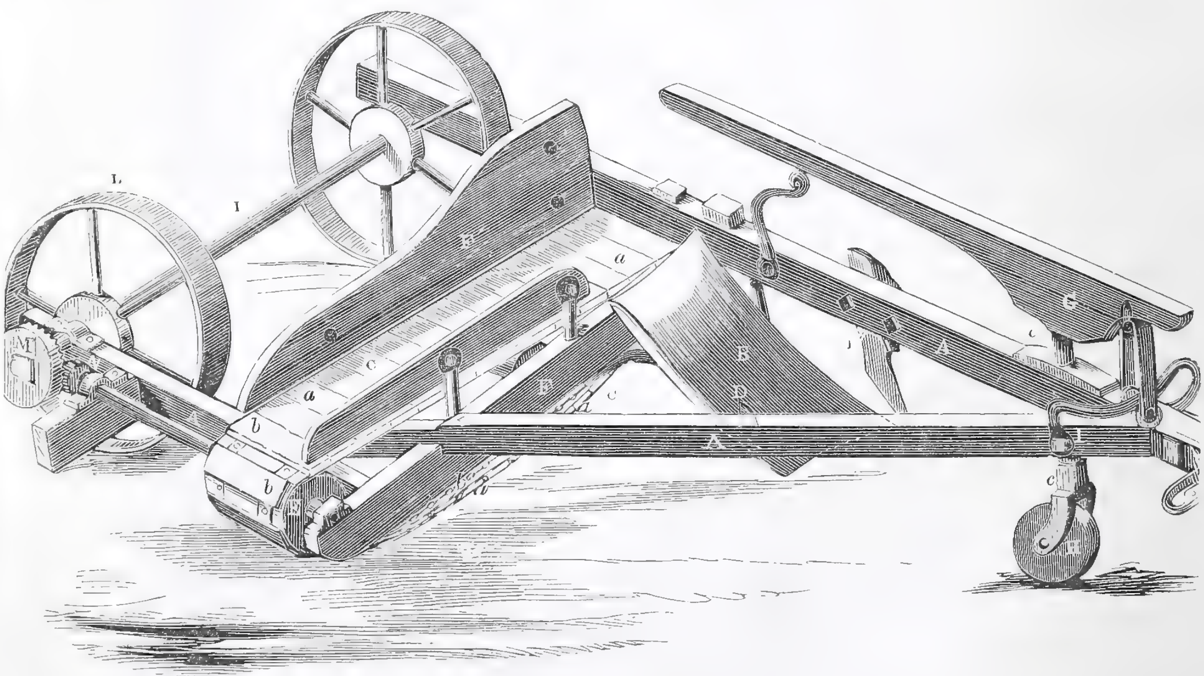
The platform and frame descend by allowing the rope to move gently down, the weight of the platform and frame being sufficient to keep the pawls free from the racks.

IMPROVED DITCHING PLOUGH.

The accompanying figure is a perspective view of the Ditching Plough of John Lyon, who has secured a patent for it in the United States.

The nature of the invention consists in a new and useful arrangement of mechanism, so as to constitute a machine for throwing up embankments in forming roads and foundations for fences, and for making open drains, &c., said arrangement rendering the machine very simple, cheap, and durable, and also very perfect in its operation.

A A′ designate a triangular-shaped frame, to which all the operative mechanism is attached, as shown; B is the ditching plough, it is attached to the beam, A′, of the frame, A, in a similar manner as a common plough. Its construction is also similar to that of an ordinary plough, except the mold-board, which is so shaped that, instead of turning a furrow over, it merely passes under the soil, and raises it to a sufficient inclination to be deposited upon an endless conveyer, C, as fast as it is cut up. The said mold-board has one of its side edges raised slightly higher than the other, so that the dirt will always clear the frame, A′, and fall upon the endless conveyer; D E are



two cutters, one attached to the beam, A′, as commonly, and the other to the extremity of the share, and opposite to the land side. These cutters facilitate the entrance of the plough into the soil; C is the endless conveyer, placed behind, and at right angles to the land side of the plough. It is composed of slats, *a a*, attached to two endless chains, *b b*, as shown in the engraving, and is thus made flexible. This conveyer is placed over a plain revolving roller at one end, and a toothed or sprocket roller, E, at the other end, and revolves on the same in a manner similar to an endless chain horse power; F F′ are two guide boards, for confining the dirt on the endless conveyer—one being on the rear edge, and the other on the front. The front guide, F, extends from the inner side of the plough to the centre of the sprocket wheel, and F′ extends from one end of the apron to the other, and has that portion which is directly behind the plough, made higher than the other part, so that the plough

may not throw the earth over the back edge of the apron. By this conveyer the dirt is taken from the plough, and deposited in the place desired, either for the purpose of forming a road, or foundations for fences. By thus receiving the dirt, and depositing it at right angles to the plough, a road of any length can be formed with great ease and despatch. G is the lever which carries the guide pulley, H, that is secured in the lower end of a vertical rod, *e*, which passes loosely through the beam, A′, of the frame, A, and connects with said lever. The extreme end of the lever, G, carries a friction roller, I, which plays under and round a curved way, J, as the lever is turned in the path of a horizontal circle, and for transmitting the power of the lever to the beam, A′, in raising the ploughshare. By raising or lowering this lever, the plough can be adjusted so as to cut more or less deep, and by moving it horizontally, the machine can be guided up to a steep bank as the team walks along the base; K is a driving wheel, arranged fast on the revolving shaft, L, said shaft being some distance in the rear of the dirt conveyer, and revolves at right angles to the conveyer; L′ is a sustaining wheel turning loosely on the said shaft, L, near its extremity; M is a bevil wheel, placed on the extreme end of the shaft, L. This wheel gears into a pinion, N, on the shaft, O, of the sprocket roller, E, as shown in the engraving—said pinion transmits motion from the driving wheel to the endless conveyer.

The operation is as follows:—As the machine advances, the plough enters the ground and raises the soil, which is forced, as the operation proceeds, upon the endless conveyer, and carried by the same as it revolves at right angles to the line of travel, and discharged at the end of the conveyer in a continuous stream, where it is laid either to form a road or foundation for fences.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER V.

THE INTELLECTUAL REFORMATION. (A.D. 1400.)

Two remarks must be made before we can resume the thread of our narrative. The development of science does not consist, as some imagine, of a series of revolutions. The opinions of every age follow, as a natural result, from those of the foregoing. At times, however, in the inward, as in the outward world, attempts are made to arrest the natural and peaceful progress of events—to maintain ideas and institutions which have lost their efficiency—to cement, as it were, the sere foliage to the branches of the great life-tree Igdrasil. That all such efforts must ultimately fail, is true. That they impart a violent and tumultuary character to what would be otherwise regular and pacific, is no less true. By damming up the channel of a river, we cannot stop its course, but we may convert the tranquil and fertilizing stream into a destructive torrent.

Further, in the intellectual history of mankind, it is impossible to mark out epochs with rigorous exactitude. The mountain peak kindles in sunshine, while the plain is still wrapt in darkness. Every idea, every principle, has its forerunners, its prophets. We shall, therefore, be compelled to group men and events rather in accordance with their spiritual connection, than with a mere chronological series. We commence this epoch, therefore, with surveying—

THE MARTYRDOM OF THE INTELLECT.

It may at the first glance appear strange that the development of intelligence, as manifested in the progress of science, should meet with persecution. Speculative research appears so remote from the common sphere of man's passions and interests, that it might be regarded, if not with favour, yet with indifference. If such be our expectations, they will be rudely shaken by the study of history. We shall perceive that almost every step in the extension, in the diffusion, or in the application of natural science, has been denounced as a crime; that almost every philosopher has met with persecution under the form customary in his epoch. We shall feel less wonder if we bear in mind that every man who differs from his age, either as being far before or far behind it, gives offence. He is not "of the world," and the world, consequently, does not love him as its own. This hostility towards all who do not agree with the common notions of their times, takes, however, two different forms. The man behind his age is looked upon with a sort of good-humoured contempt. It gratifies our pride to see others unable to conceive truths which to us have long been familiar. But the man in advance of us, "sitting where we durst not soar," is a humiliating spectacle. To hide the feeling of our inferiority, we call his speculations dangerous, and demand their suppression. There is a "*jacquerie*," a sansculottism, if we may so speak, directed against the aristocracy of intelligence; and many who repudiate all communist inroads upon material wealth, harbour a malignant envy against all minds that rise above the average level.

The general indifference felt towards intellectual pursuits is no safeguard. Persecution depends upon the active ill-will of a few, to which the careless many grunt assent; too happy to hang or burn any poor sinner, so they may sleep on, and be spared the trouble of thinking. Science, moreover, has very rarely been persecuted under its own name. That, even in the darkest ages, might have been no good policy. The philosopher was accused, not of being wiser than his neighbours, but of heresy, infidelity, witchcraft, or disloyalty—accusations difficult to rebut from their very vagueness, and admirably adapted to excite the fears and suspicions of kings and of peoples. It has been even maintained that philosophers only incurred danger, if they unadvisedly interfered with theology or politics. The writers who urge this extenuation show that they have been misled by the pretexts brought forward by the persecutors. It is the very essence of persecution to have an outward ostensible pretext, totally distinct from its actual inward motive. It is this which distinguishes persecution from the just and necessary punishments which society inflicts upon evil-doers. Society dreads the murderer as a murderer, and punishes him for murder. Bigotry dreads the enlightened man for his intelligence, and punishes him for—sorcery or infidelity! Bearing these facts in mind, we shall treat the offences stated in the indictment as mere pretexts, and shall look deeper.

Let us now examine from what quarter the persecutions of science most emanate. A despotism it must be; a power claiming uncontrolled sway over mankind. If our very thoughts are placed under criminal jurisdiction, what liberty can we claim for our words and actions? But military or civil despotisms rarely interfere with abstract speculation. They even encourage it as a safety-valve for the pent-up energy of mankind, and rely upon chains and bayonets to suppress any ill consequences that may possibly arise. Ecclesiastical despotisms, wiser in their generation, know that where thought is enslaved, outward actions are little to be dreaded. They know that the man who dares not think for himself is his own jailer and his own dungeon, and needs neither chains nor bayonets to "keep him down." It is here, therefore, that we must seek for the power inimical to intelligence, and amply does history confirm what we have thus been led to expect. Wherever science has been persecuted, it has been either at the instigation, or by the direct authority of clerical corporations. We hasten to meet a possible misunderstanding, or rather misrepresentation. There is not, in our opinion, any necessary antagonism between science and religion. It is not Christianity, but priesthoods, established churches, claiming to be estates of the realm, grasping at secular power, and especially seeking to sway public education, whence the enmity to science proceeds. Every such body, we believe, is, according to its power and opportunities, more or less actively opposed to the spread, the development of intelligence, and, above all, to the cultivation of physical science.

In antiquity, comparatively little of this feeling was manifested. The national religion of Greece and Rome was certainly incompatible with the teachings of philosophy; and the most eminent thinkers were from time to time accused of infidelity, and subjected to banishment. These events were, however, mere occasional outbursts of popular fanaticism; stimulated,

perhaps, by individual jealousy; not an organized opposition. There was no trained and disciplined clergy, who felt the suppression of thought their peculiar duty. Accordingly we find public education committed, not to the priests, but to the philosophers. With the rise of Christianity a change soon appeared. Although its doctrines in themselves presented none of that incompatibility with science which we trace in the Greeco-Roman polytheism, a variety of causes tended to set it in opposition to human learning. The philosophy of the day was confounded with the religion of its former cultivators, and was denounced as heathenish. The teachers of Christianity soon showed a desire to become the sole teachers of mankind, and to extract from the Scriptures a philosophy as well as a creed. The persecution to which the early Christians were exposed, prevented them from attending the public schools, and obliged them to establish schools of their own, which, as might naturally be expected, were placed under the supervision of the clergy. The spirit thus fostered was not long in making itself felt, as soon as it received free scope from the religious revolution under Constantine. The fearful death of Hypatia, already mentioned as the proto-martyr of intelligence, was a significant opening to the great tragedy. The bishops, now recognised as officers of the empire, were intrusted with a share in the management of national education. The philosophic schools of Athens were closed by imperial edict. Scientific writings were committed to the flames by a one-sided zeal, as magical and satanic. With the decline of learning, the influence of the clergy over public education increased; ultimately to the exclusion of all others. From such purely incidental circumstances springs the modern claim of ecclesiastics to the oversight of universities and schools! When in after ages secular learning revived, this claim remained. A "*vesana admixtio*"* confounded the respective spheres of faith and knowledge, of priest and philosopher, of church and school. The sciences were viewed as portions of theology, and were stripped of all independent being. The views of Aristotle, seen through the medium of bad Latin versions, were blended with the dogmas of the church, and promulgated as an orthodox, an authorized philosophy.† The Stagyrite, it was said, had not merely enounced all truth, but expounded it in the best possible manner. All, therefore, left for posterity was to comment, to illustrate, to collate his views. To dissent from the received opinions was heresy, infidelity. Thus an embargo was laid upon all progress, and the loftiest energies of the human mind consigned to an apparently eternal slumber. The intellect, like Prometheus, was chained down to a rock by clerical arrogance and authority. Henceforth the professor might teach, but it must be merely what the church ordained; the author might publish whatsoever the pope or a council were pleased to sanction; the philosopher might meditate, but woe to him if he discovered anything not contained in the established system. Had this system been able to maintain itself, modern Europe would have been the image of China. We should have seen nothing but the fossil remains of an extinct spiritual life. Fortunately this state of things did not last. Men arose to defy it, and ever as one perished for the truth, another came forward to tread in his footsteps. Thus, for several ages, raged the war between reason and authority. It was indeed a fearful contest. On the one side we see a haughty priesthood combating for universal dominion, wielding every weapon that force or fraud could supply, surrounded with jailers and tortures, and backed by the power of civil government. On the other, a few despised men, armed with the everlasting fire of genius, relying on their godlike cause, and even in the agonies of death still proclaiming the great charter of humanity—the right of every man to think for himself. This it is which gives such high, such world-wide significance to the struggle. The very germ, the inmost life of freedom was at issue. The propagation of truth was in those days no easy matter. The philosopher could not, as now, saunter to Paternoster Row and arrange with his publisher. No; fleeing from country to country like a contrabandist, lurking in woods and solitudes like a bandit, watched like a conspirator by spies and informers, he stood in constant jeopardy. It is very easy for us to blame their imprudence. Ideas cannot be promulgated without utterance, and in every utterance there was danger.

Amongst these worthies there are three whom we shall select as types of the whole class. The first of these we are proud to claim as our countryman. Born in one of the dreariest periods of the dark ages, amid a chaos of mingled sensuality and bloodshed, of pedantry and superstition, Roger Bacon* stands forth more glorious for the encircling gloom. He was born at Ilchester, in Somerset, in 1214, and received his education at Oxford, which *then* was in advance of the age. From Oxford he proceeded to Paris, at that time the most distinguished university in the world. Here he read Aristotle, without, however, like too many in those days, accepting him as infallible. His studies being completed, he returned to Oxford, then under the management of the Franciscans. To obtain right of delivering lectures, he was obliged to enter that order. We find Bacon, in 1240, duly installed in his office, teaching and lecturing, and also reading, meditating, and experimenting with all earnestness. His conduct and manners soon began to draw attention. He is not like the other professors. Instead of taking the old authors for granted, and expounding them in the old manner, he calls them in question, doubts their accuracy, and appeals to reason and experience. He believes his own senses rather than Aristotle. The students flock to hear him, and feel a new light breaking in upon their minds. But the monks look on in angry amazement. "Brother Roger," they find, will take no man's word for granted. Listen to his bold sayings: "There are four stumbling-blocks in the way to knowledge—authority, habit, appearances as they present themselves to the vulgar eye, and the concealment of ignorance. We must, with all strength, prefer reason to custom." All this may sound to us very simple and commonplace, yet six centuries ago it appeared novel, indeed alarming, and almost blasphemous. It was a voice of terror to many hollow heads and hollower hearts. "Truly," said the monks, "Brother Roger is a strange man; it is to be feared that he thinks." When enjoying their sleep in the night, and their meditations (?) after dinner, they are disturbed by strange noises and flashes of light. Those who visit Roger find his apartment filled with furnaces and alembics breathing out sulphurous vapours. They see scrolls covered with lines and circles, which to them are a mystery. He has invented gunpowder and the telescope, and is prying boldly into the recesses of nature. They understand not his designs. In the quaint language of Anthony à Wood, they thought that "the points of a triangle would wound religion, and the only property they knew of a circle was keeping out the devil." They cannot enter into Bacon's glorious hopes, his sublime thirst for truth. Life in the intellect appears to their sensual souls mere foolishness, or even an abomination. Accustomed to ascribe everything unusual to supernatural agency, they proclaim the noble thinker a sorcerer. Fiends are said to visit his cell nightly, and instruct him in forbidden lore. The more simple of the monks believe this rumour, and are heartily thankful that they have never devoted themselves to learning and become conjurors—which was most true. Others admit that learning is a good thing, if followed under the sanction and guidance of the church, and not carried too far; but a man like Bacon, who has relied on his own unassisted judgment, is, in their opinion, deserving of all censure. Even those who laughed at witchcraft found it an excellent pretext against Bacon. They saw that he was raising a spirit fatal to their sway; that he was teaching men to read, without inquiring by what council the work had been sanctioned. For the foes of truth are sharper-sighted than its friends. His ruin is determined. As the first step, they prohibit him from teaching in the university, or from circulating his papers. The accession of a new pope promised a change in his situation. Clemens IV. was a man of some liberality, and had on a former occasion expressed an interest in his researches. The support our hero received from this pontiff enabled him to make his ideas public. He drew up three works, the *Opus majus*, *minus*, and *tertium*,

* "Mad mixture."—*Bacon.*

† The authority of Aristotle underwent, however, many vicissitudes at the hands of his infallible interpreters. His works were read in the university of Paris in the 13th century, prohibited by a council in 1209, restored to favour about 1215, prohibited again by Pope Gregory IX. in 1231, and afterwards admitted into permanent favour.

* The name is more properly *Beacon.*

and forwarded them to the pope, who could not refrain from admiring their merit. The former of these—of which an edition appeared about the middle of the last century—contains a general view of science as then known, with valuable suggestions for its improvement. The author points out, in forcible language, the high claims of physical science, and the manifold advantages which it was destined to confer upon mankind. This, too, we must remember, at a time when science scarcely existed, save in his own prophetic intellect. The *Opus minus* and *Opus tertium* exist only in manuscript; the former is a compendium, the latter a supplement. On the death of Pope Clemens the persecution began in earnest. A papal legate, Jerome of Ascoli, a man every way qualified for the work, arrived at Paris, duly empowered to punish all thinkers, and Bacon, now is his 64th year, was summoned to stand his trial. Of the proceedings little is known. We are merely told that he was accused of "innovation," and found guilty of thinking for himself and telling the truth, or, in the cant of the age, of "heresy and witchcraft." The judges doom him to perpetual imprisonment, and themselves to lasting infamy. His writings are condemned as blasphemous, and their perusal forbidden under penalty of excommunication. The pope was "graciously pleased" to confirm the sentence. The remaining days of the philosopher are lost in obscurity. It is certain that he remained ten years in a loathsome dungeon, and that his treatment was deemed unusually rigorous, even in that merciless age. Some maintain that he died in prison; others that he was at length set free, at the intercession of certain powerful nobles. He is said to have been buried in the Franciscan church at Oxford. Such was Roger Bacon, a man so far in advance of his age as to be "beyond its ken." He applied himself with great diligence to the study of chemistry, and was the first European who prepared gunpowder, though he may have received some hint concerning its nature from the East. In optics he was likewise successful. He is generally supposed to have been the inventor of spectacles. The structure of the telescope is also described in his works. To us, his remarks on the advancement of science form the most interesting portion of his works. It has been said, not without reason, that were he to revisit the earth, he would shake his head at the little progress we have made. His works are distinguished for the ease and clearness of their style. His whole being was merely a prophecy, scorned by his contemporaries; and many gifted men had to share in his sufferings before that prophecy could be fulfilled. One reflection we cannot suppress. How little of Bacon's spirit has rested upon the university where he taught! From the *Opus majus* of Roger Bacon, to the *Christian Ethics* of William Sewell,—oh, "what a falling off is there!"

The scene now changes from England to Italy, and from the 13th to the 16th century. The intermediate time has had its struggles and its triumphs, and, despite the trammels of ecclesiastical authority, has not been spent in vain. A general movement is in progress; man grows more inquiring, bolder, more self-reliant. Scientific societies or academies* were formed in various countries. Above all, a new power appeared in the field, whose tendencies soon became manifest: it need hardly be added that we allude to the glorious invention of printing. The ecclesiastical party—who dread an enemy in every new invention, just as the murderer takes every shadow for an officer of justice—endeavoured by a variety of restrictions to strangle the infant Hercules. Berthold, Archbishop of Mainz, stands "damned to everlasting fame," as the first who appointed regular censors to examine all books; and severe penalties were soon denounced against all unlicensed publishers. But though the spread of knowledge was thus retarded, it could not be entirely arrested. Wherever the press was carried, thinkers seemed to spring up as by enchantment, in spite of censorships and inquisitions. Such was the mental condition of Europe when astronomy became the battle-field between authority and reason. A brief recapitulation of the views then taught in the universities may be acceptable. The earth was supposed to be fixed in the centre of the universe, the largest and the only inhabited orb. The sun, moon, and stars, existing only for its convenience, were small bodies revolving round it, or set in various solid heavens or firmaments. Beyond all lay the *primum mobile* which set everything in motion. A rigid line of demarcation was drawn between *earth* and *heaven*. The heavenly bodies were not masses of rock like our globe, with land and sea, mountain and valley, but were in their nature perfect, pure, spiritual; only the moon, as being the "lowest down," and nearest our world, was defiled with earthly stains. This cumbrous theory rested on the totally vicious conception of "man, the measure and object of all things." It was extracted from the works of Hipparchus, and was supposed to be supported by various passages in the Scriptures. Accordingly, it enjoyed the sanction of the church. To doubt it, was not simply to differ from the bulk of the learned world, but to incur the imputation of infidelity. At length Copernicus, struck with the absurdities of the reigning system, set it aside; and reviving the opinions commonly ascribed to Pythagoras, he taught that this our earth was only one of a number of bodies, all revolving around the sun. "Does the earth move or the sun?" was now the question at issue. The starry heavens were the magnificent battle-field where the future freedom or slavery of the human mind was to be decided. Was it not, therefore, by a beautiful instinct that man had been led to look up to those remote orbs as the oracles of his destiny? We must now notice one of those who took a prominent part in this great struggle, and who died gloriously in and for the truth.

Giordano Bruno was born, in the sixteenth century, at Nola, in the kingdom of Naples, a region then literally radiant with the dawn of intellectual life. Alas! that the sacred land of the Pythagoreans should now lie as the Pariah of nations, its very soul trampled out beneath the hoofs of the Holy Inquisition! On reaching manhood, Bruno became a monk—still the only recognised profession for a studious character. He met, however, with difficulties in the monastic life. Naturally of a bold and inquiring disposition, the question "why" was ever upon his lips, to the great annoyance of his superiors. At last he found it advisable to make a hasty retreat from his convent, and retire to Geneva, where pope and inquisition were powerless. Here he declared himself a Copernican. The Calvinist clergy, supreme in this city, were not more favourable to speculative philosophy than the Catholic priests of Italy. Bruno gave offence by his freedom of speech, and a second flight was the result. He repaired to Paris, where his eloquence and learning earned a favourable reception. He was permitted to lecture on philosophy at the university. Many of the principal nobility gave him their countenance, and he seemed destined to settle as head of the scientific world in the French metropolis. Yet his attacks upon the old system of philosophy raised him up so many enemies, especially among the clergy, that, in 1583, he accompanied his friend, the Marquis of Castelnan, who was sent as ambassador to the English court. Here he formed an intimate friendship with Sir Philip Sydney. Whilst in England, he published his views on positive science and metaphysics. In the latter department he appears to have anticipated some of the doctrines of Spinoza. He wrote also some satires against the clergy, whose hatred needed no such stimulant. In one of these, entitled a "Dialogue between Pegasus and the Ass of Silenus," he ironically maintains that ignorance is the mother of happiness. We find him next leading a wandering life in Germany; visiting in succession Marburg, Wittenberg, Helmstädt, and Frankfort, his career everywhere a protracted martyrdom. A fugitive throughout Europe, he raised everywhere the standard of revolt against authority, and everywhere proclaimed the truths of the new philosophy with a zeal that knew no repose. At last he suddenly quitted Frankfort and hastened to Padua. Here he defended the Copernican system with his usual boldness. In 1594 he removed to Venice, and here he was suddenly arrested by the familiars of the Inquisition. He knew well what to await. Life could only have been granted him on terms the most humiliating, and submission never entered his mind. He remained, however, a considerable time in prison, under the usual infliction of examinations and remands. In 1598 he was removed to Rome, where he remained in confinement till the 9th day of February, A.D. 1600. This was the

* This once sacred word having been seized upon by the Squeers fraternity, is no longer fit for use.

day fixed for his trial, if trial it may be called, where the sentence has been determined years before. He is brought before certain sons of darkness, and condemned to the flames as a heretic and infidel.* On the 16th of the same month the tragedy is to take place. The Campo di Fiore is filled with a vast crowd eager for the sight. And now comes the martyr; his step as stately, his brow as calm, as if the multitude had met to do him homage. The monks exhort him once more to renounce his doctrines. He heeds them not. An officious friar thrusts a crucifix into his face, but he turns away his head with an exulting smile. Fire is laid to the pile, and in little time a heap of smouldering ashes are the only visible trace of Giordano Bruno. "Thus," says Scioppius, classical pedant, and platelicker in ordinary to the cardinals—"thus we deal with heretics and blasphemous men at Rome." Yet this rejoicing is dashed with unpleasant forebodings. They have burned the thinker, but his thoughts they could not burn. The superb reply of the martyr to his judges was true: "Ye feel more fear in pronouncing this sentence than do I in receiving it!" "Another such triumph and I am undone," said Pyrrhus of old, after a hard contest with the free people whom he sought to enslave. Very similar must have been the reflections of the priesthood over the ashes of Bruno.

The career of Galileo has been too often described to require repetition. We will merely append a few remarks. It was this illustrious man who, in his letter to the Grand-duchess Christina of Tuscany, first developed the doctrine of the *compromise*, which had been sketched by Bruno, and which is now accepted both by all philosophers and by all enlightened theologians. He showed that the Scriptures neither possess nor claim any authority on scientific questions; that on all such matters they employ the phraseology current at the period when they were written. This doctrine, fully accepted, must prevent all hostility between religion and science, until either in this or in a higher state the harmony of all truth shall be recognised.

The recantation which Galileo was compelled to pronounce contained the following passage: "With a sincere heart and unfeigned faith, I abjure, curse, and detest the said heresies (namely, that the earth moves). I swear that I will never in future say or assert anything, verbally or in writing, which may give rise to a similar suspicion against me. I, Galileo Galilei, have abjured as above with my own hand." This momentary submission, due in part to years and infirmity, was a godsend to his persecutors. But truth did not long forsake her champion. Rising from his knees in that accursed hall, he uttered the Promethean words: "It does move for all that!" Sentence was now passed, clad in all the declamatory bombast which such a mockery might require. The following passages will show its nature: "The proposition that the sun is the centre of the universe, and immoveable from its place, is absurd, philosophically false, and formally heretical, because it is expressly contrary to Holy Scripture. The proposition that the earth is not the centre of the universe, nor immoveable, but that it moves, and also with a daily motion, is absurd, philosophically false, and, theologically considered, at least erroneous in faith. We decree that the book of the dialogues of Galileo Galilei be prohibited by edict, and we condemn you to the prison of this office during pleasure." The disgraceful mummery being ended, Galileo was led back to prison, while his sentence and abjuration were ordered to be published in all the universities, and in the church of Santa Croce at Florence, where his friends were compelled to be present. But here, again, as in the former cases, the church found that nothing was gained. At first, indeed, the scientific world felt intimidated, but a reaction soon commenced. No one could attach any lasting weight to an abjuration obtained on the "stand-and-deliver" principle. A healthy indignation spread through Europe, and greatly promoted the cause of free inquiry—that cause of which his name was now the watchword. The convent of Minerva was our Thermopylæ. We need, therefore, feel very little surprise at the attempts made to injure his reputation, or to conceal his true position as the martyr of the intellect. Certain hackney scribblers deny, with the air of injured innocence, that he was put to the torture. Be it so. If there be any doubt, they are, in legal phrase, entitled to the benefit thereof. But if they treated him with any degree of consideration, it was because they knew that their day was fast drawing to a close. Enlightened public opinion was rising upon them, and the echo of its surge reached them on the judgment-seat, despite of guards and jailers. If Galileo escaped the rack, he might thank their fears, not their mercy. But the whole question is irrelevant. We have simply to ask, "Did an ecclesiastical tribunal presume, no matter how 'mildly and respectfully,' to pass judgment on a philosophical question?" The church, even if asked to decide such matters, should have replied in the too often forgotten language of her founder, "Who made me a judge between thee and him?" Were the Court of Chancery to pass judgment on some question of social etiquette; were the patronesses of Almack's to adjudicate some moot point of international law; or were the Royal Society to insist on deciding some commercial dispute, the outrage on common sense would be no greater.

Some have attempted to show that Galileo was the author of his own misfortune; he was rash, they say, and "petulant." Not content with advancing the new philosophy as a mere hypothesis, he insisted on its recognition as absolute truth. Had he been more cautious and submissive, he might, like other champions of the same doctrine, have gone to the grave in peace. We are no advocates for imprudence. For most men, and at most seasons, to take prejudices in the flank is the safer policy. Still there are cases when some one must stand in the breach; seasons there are when the kings of thought are summoned to consecrate with their blood the cause they have followed through life. It is easy to be "prudent" in our age. Galileo might, forsooth, have veiled the light of science in the rags of worn-out superstitions, to suit the bleared eyes of bigotry. All then would have gone smoothly. But we may thank Heaven that he knew his duty better, for it is to such imprudence that we owe every spark of light and liberty we possess. Concerning the vilifiers of Galileo, we can only exclaim, How long shall the obscene harpies of retrogression be permitted to pollute with their ordure the high places of the intellect! How long shall they gibber their "hangman's jests" over the graves of our martyrs!

Dr. Whewell supposes that, throughout the trial a good understanding prevailed between the prisoner and his judges, that the abjuration was merely given to save appearances; and that the great "It does move for all that!" was regarded by the authorities as a capital joke. But how can the rigorous treatment of Galileo be reconciled with such a view; his perpetual imprisonment, his seclusion from friends and disciples, the continued surveillance of the Inquisition, the suppression of his works, his burial in an obscure corner, and the prohibition of a monument to his honour? We can only infer that his persecutors were actuated by the most unrelenting malice.

Such is an account of the three most eminent martyrs of science. That these were no exceptional cases, the following facts will prove. Telesio, who, in the 16th century, opposed the Aristotelian system, was accused of atheism, and obliged to flee from city to city for refuge; Campanella, a little later, was put to the torture, and imprisoned for twenty-seven years. Cæsalpinus, the botanist and anatomist, was kept in constant dread for his life. Ramus was denounced, banished, his property seized, and his writings condemned, and he was ultimately put to death during the massacre of St. Bartholomew. Vanini was burnt at the stake in Toulouse; his tongue having been previously torn out. Stephen Dolet and Gottfried Valer were executed under the pretext of atheism. On September 4, 1624, the Parliament of Paris, at the request of the Faculty of Theology, issued a decree against Jean Bilault, Antoine Villon, called the philosophical soldier, and Etienne de Claves, apothecary, who had posted up theses against the doctrines of Aristotle for public discussion. After having ordered the theses to be torn, it commanded the authors to quit Paris within twenty-four hours. It was added, "Be it forbidden to all persons, under pain of death, to hold or teach any maxims against the ancient and approved authors, or to hold any discussions, save

* The sentence was couched in words literally *reeking* with hypocrisy. "*Ut quam clementissime et citra sanguinis effusionem puniretur.*" "That he be punished as mercifully as possible, and without effusion of blood!!"

Parts of Fructification _ Corolla, continued. PLATE IX.

Nectarium.

such as shall be approved by the said Faculty of Theology." Five years afterwards the same parliament repeated similar injunctions against some "extravagant chemists;" observing, "It is impossible to attack the philosophic principles of Aristotle without attacking those of the scholastic theology received in our religion." In 1468, Pomponius Laetus, Platina, Experiens, and several other learned men, were arrested by Pope Paul II. on a charge of "heresy and infidelity," and put to the torture. In 1542, the members of the Academy of Modena were compelled to sign a renunciation of their "errors," and their chairman, Bernard Ochino, narrowly escaped with his life.

AGRICULTURE.

CHAPTER XVII.

BREEDING.

In the course of the last century very great improvements have been made in our domesticated animals. Cattle, sheep, and pigs now come to maturity in about half the time, and at less than half the expense they used to do. This has been brought about partly by observing what are good points, as they are called, *i.e.* good external physical appearances, and partly by acting upon the belief that these points are transmitted from parent to offspring. When we see that so much has been done upon so little premises, we may hope that by-and-by much greater results may be obtained. We here attempt a brief outline of the leading principles ascertained with regard to reproduction. If we can obtain enlarged ideas upon this subject, we may be assured that the subject of breeding, at present so difficult to the farmer, will become very much simplified.

Some of the lower animals, like most plants, may be propagated by budding, that is, a piece cut out of them and placed under certain conditions, may be developed into a perfect animal. This, however, is only true with regard to animals low in the scale. In general, it is necessary for the reproduction of animals that there should be two sexes, and that of these one, a female, should secrete a germ, or embryo animal, which can only be called into actual existence, however, by having applied to it a secretion from the male.

After, however, the germ has been successfully impregnated by the male secretion, a store of nutriment is placed around it in the shape of albumen, &c., to nourish it during its embryo life. Sometimes this is at once expelled in the shape of an egg, and brought to maturity by the application of heat, by the parents lying over it, &c.; and at other times the impregnated egg is retained in the body of the female, and hatched in it by the heat there present in the circulating blood. The former of these processes is the one we witness in poultry, and the latter in cows, swine, and the like. We call members of the first class oviparous, and those of the second viviparous, in their reproductive habits.

Generally speaking, the germ of a female animal can only be fecundated by the secretion of a male of the same species. But occasionally two animals of a different species, but nearly allied to one another, can produce, by having sexual intercourse together, an animal resembling both parents, and blending their peculiarities. Such productions are called mules, because the most common example that we see of such a production—the offspring of a mare and a jackass—is called a mule. But all these mules, although there are, perhaps, a few exceptional cases, are incapable of reproducing their species, or of breeding with either of the species from which they have sprung.

Now, it is a most certainly established fact, that the offspring tends to inherit the properties and the peculiarities of both parents; and this is true, not only of physical appearance, but of physical endowments, as aptitude to fatten, spirit in draught, and even of mental qualities. Upon this clearly established fact depends the art of breeding. Certain internal signs are considered indicative of certain properties, and such parents are selected as possess these, in order that they may be transmitted to and blended with the expected posterity.

A great many of the so-called points are probably altogether unconnected with real good qualities. Upon this, as upon all points connected with practical farming, a great deal of empiricism prevails. In breeding animals destined for food, the one great end which it is desirable to attain is to have the meat most developed upon those parts most esteemed for food, and least upon the offal parts. Hence small bones, little heads, and short legs, are endeavoured to be propagated. The deposition of fat is unquestionably favoured, and its being used in the system prevented, by a lazy, placid disposition. This is as much transmitted from parent to offspring as peculiarities of physical structure.

A large abdomen is a sign of large digestive organs, and this, perhaps, should be a point always aimed at by the breeder of sheep and oxen.

In breeding horse, on the other hand, we are anxious to propagate considerable size of bone, strength, spirit, and a fully developed chest, more than an abdomen.

The opinion now almost universally held with regard to the comparative influence of the male and female parent is, that the former has more than the latter, and accordingly the greatest attention is paid by breeders to obtain stallions, bulls, and rams. But this belief has probably been carried too far. At any rate, among other peculiarities transmitted by the mother to the progeny, the constitution, with regard to health and the mental temperament, seem prominent.

It is now common to employ male and female of different breeds, and thus to produce *crosses*, as they are called. When the male has superior breeding, *i.e.*, more good points and qualities than the female, these crosses are always found profitable. But it is not prudent to attempt to breed again from crosses.

We merely allude to some recent speculations of Mr. Watkins regarding the influence of the parents, and the share each has upon the offspring, to denounce them as worthless.

BOTANY.

CHAPTER XII.

PHENOMENA OF THE ASCENDING SAP.

A local motion taking place in the cells, called Rotation (*rota*, a wheel), is conspicuous among the phenomena of moving fluids in plants. This study is microscopic; and the conditions of inspection are, the fluids must contain particles of different refractive power or intensity, and the cellules should be of sufficient size and transparency, to be commanded by a magnifying power from 100 to 500 times linear. Incrustations of carbonate of lime sometimes surround the stems of plants, in which it can easily be seen; in these cases, a portion must be scraped off to remove the opacity. It has been found (without reference to seaweed, which, when dried by evaporation, readily imbibe salt water) that pricking, cutting, crushing, or other forms of violence, lead to a suspension of this curious appearance, in several cases extending to half an hour or more; when perfect rest, and the application of a little warmth in a vessel of water, will lead to its renewal.

So long as the year 1774, Abbé Corti, of Lucca, published some observations on circulation within the cells of certain aquatic plants, among which was the Naiad, Caulinia fragilis. Little notice seems to have been taken of this remarkable discovery, until confirmed by Treviranus in 1817 (Ann. des Sc. x. 22); and shortly after, Amici, of Modena, in two memoirs which appeared in the Transactions of the Italian Society, vols. xviii. xix., communicated the result of his researches on most of the species of Chara or Stonewort; in every tube of which, setting from one transverse partition to the other, and ascending and descending on the cell walls, the current was seen to run, in Common Chara, at the rate of about two lines per minute.

The subject now attracted general interest, and the study of Charas has been enriched by the magnificent dissections of the British naturalists, Mr. R. H. Solly, Mr. Slack, and Mr. Varley, who have extended their examination into the other genera of this order, particularly Nitella. (Transactions of the Soc. of Arts, xlix. 177, l. 171, and Trans. of Micros. Soc. ii.) The

most careful inquiries have also been pursued abroad. The moving fluid contains certain granules, which turn to yellow when treated with iodine; but the most remarkable are globules of a green colour, which remain, some attached to the cell wall while others join free in the rotation. Amici established the fact, that the rows of green globules, which line in great numbers the inner coat of each cell, determined the course of the current, as it spirally meandered among these irregularly set specks; for the direction is more or less spiral. Schleiden ascertained that the moving fluid is denser than the cell sap. Becquerel has attempted to prove that the moving force of the globules is not due to electrical or magnetic attraction and repulsion in the contents of the cells; though the researçhes of Donné (Ann. Sc. Nat. Série 2, i. 125) imply a general electrical current in plants as well as in animals, determined by the acid or alkaline quality of their fluids. Donné, however, cast some light upon the cause of the motion, by finding that every individual granule is not only specifically affected by whatever accelerates or stops the current, but that an innate power of rotation on its own axis resides in each globule when separated from its adherent membrane. A. Brongniart and Dutrochet have confirmed the motion of each detached globule, as entirely independent of the general circulatory current. Minuter details respecting the Charas will be found on consulting Ann. de Chimie, xiii. 384; Ann. des Sc. ii. 41, x. 22; Ann. Sc. Nat. 2d ser. ix. 5, 65, 80, x. 346.

The next cellular plant exhibiting a favourable view of rotation, was the Two-Stamined Vallisneria, in sections either of the leaf, calyx, flower-stalk, or root. "Its natural habitat," says Quekett (Practical Treatise on Use of the Microscope, 2nd edition, p. 379), "is the still portions of rivers and lakes. When growing, its appearance is not at all inviting, as it very much resembles so much grass in the water, the long thin leaves being secured to the mud by numerous white hair-like roots. But to compensate for its uninteresting appearance, the phenomena of the circulation disclosed by the microscope is, without doubt, the grandest that has as yet been seen in the whole vegetable kingdom. If one of the leaves be laid on a glass slide, and a sharp knife passed along it, with its back slightly elevated, so that its edge may come in contact with the leaf, a thin slice may be cut off; this, when placed under a power of 200 diameters, will exhibit a number of oblong cells, more or less full of green granules, which, generally speaking, will be found to be in continual circulation round the walls of each cell. If the section should chiefly consist of the outer part or cuticle of the leaf, the cells will be small, and the green globules, termed chlorophylle, in the greatest abundance, but rarely circulating; if the section should extend through the middle of the plant, numerous elongated colourless cells will then be seen with green particles only present on the margins, and these in active circulation, and accompanying them a large, more or less transparent, nucleus; the movement of the granules is more plainly seen than in the Chara and Nitella, on account of the transparency of the cells, and also by reason of the great contrast between the colour of the cell walls and that of the granules. The circulation also will be frequently found to vary in its direction, in two cells lying side by side, which is another material point in which it differs from all the tribe, either of Chara or Nitella." This last remark points to a fact of much interest, namely, that the currents take different directions in different cells; though in each cell the rotation is uniform, and when suspended by cold or other agency is always resumed in its former way. Mohl contends that in other plants there are several cavities in each cell, but in the present only one, giving rise to the simple action of a stream running from the nucleus to the cell wall. These mucilaginous lines, he says, remain occasionally defined on the cell wall after rotation has ceased, and shows the method in which spiral fibres are formed. The inquiry is certainly most suggestive, and well worthy of being pursued for the purpose of ascertaining, if practicable, the characteristic share of rotation, circulation, and cyclosis in the construction of tissue, or in the functions of nutrition and secretion, throughout the different classes of the vegetable kingdom. It is conducive to facility of examination, that portions of Vallisneria kept in a phial of water are found to exhibit motion for several days together, and even for a month, after being detached.

From the scrutiny carried on, the phenomenon has been discovered in the stipulæ of the leaves, in the stem, and in the ends of the roots, of Frog-bit. An account has appeared from Mr. Slack, in the Trans. of the Soc. of Arts, vol. xlix. A large spiral vessel pervaded the fragment, and in the cells, on either side, he observed a motion of oblong globules of green colour, and in some a transparent nucleus, entering into the circulation. It has been also detected in Pond-weed, Common Arrowhead, &c.

The plants hitherto noticed are all aquatic, and grow either wholly or partially submerged in stagnant, salt, or fresh water. They are also almost entirely of a cellular texture. But in the phanerogamous sort, living in the air, the structure of which is increased in complexity, the same function becomes visible in the young cells. In 1828, Dr. Robert Brown observed it in the jointed hair of the filament of the anther of Common Virginia Spiderwort. (Tradescantia virginica.) Mr. Slack and other botanists afterwards described it in full. The hair is composed of three elongated cells of great delicacy, resting on a broader and shorter cell. The line of movement in each cell is circumscribed by a fine pellucid membrane; and in each there is also a large nucleus, accompanied by small globules, as in other plants. In the base cell, a nucleus usually fixed to the wall is the point from which two or more currents radiate, and where they intersect; while in the three cells resting endwise on each other for a body, the nucleus is carried along in the current. Similar phenomena may be shown in the petal, and in sections of the stem and leaves. Schultz (Ann. des Sc. Bot. Série 2, x. 327) maintains from this illustration, that the cells form a system of vessels, which, by intercommunicating, constitute a general circulation.

To Mr. Slack we are further indebted for an account of rotation in a hair from the corolla of a species of Pentstemon, in which the molecular movement is diversified. The hair is formed of one continuous cell erected on the cuticle, and the currents move in various directions, some passing to the top, others returning at half-way, and two currents often uniting to form one. The absence of any observable nucleus enhances this anomalous system.

Mr. Holland, in 1832, was the first to observe rotation in the hairs of the leaf-stalk of Common Groundsel (Senecio vulgaris). The hairs surrounding the flowers will also yield it. The movement of the globules, though more delicate, resembles Spiderwort. A triplet microscope was the instrument employed in this discovery; and a magnifying power from 400 diameters should be used.

In the conical hairs of Common Nettle, a granular current pervades the cells; and Mohl investigated it in Berry-bearing Nettle (Urtica baccifera) and Pompion (Cucurbita pepo).

We subjoin a statement of the velocity of currents ascertained by Mohl in various plants at 66° to 68° Fahr. measured across the field of a micrometer to the strokes of a second's pendulum:—

Filamental hairs of Tradescantia virginica, $\frac{1}{300}$ to $\frac{1}{900}$ of a Parisian line in a second; mean, $\frac{1}{500}$.

Stinging hairs of Urtica baccifera; quickest, $_{627}$; slowest, $\frac{1}{875}$; mean, $\frac{1}{750}$.

Hairs of Cucurbita pepo; quickest, $\frac{1}{770}$; slowest, $\frac{1}{2700}$; mean, $\frac{1}{1857}$.

Leaves of Vallisneria spiralis; quickest, $\frac{1}{125}$; slowest, $\frac{1}{600}$; mean, $\frac{1}{183}$ of a line in a second.

Cellular tissue of young shoot of Sagittaria sagittifolia, $\frac{1}{726}$ to $\frac{1}{1056}$; mean, $\frac{1}{854}$.

Leaf of Sag. sag., $\frac{1}{1170}$ to $\frac{1}{1360}$; mean, $\frac{1}{1255}$.

If the process of rotation be the particular agency employed in organizing vegetation, producing cell after cell, and agglutinating them together, is the general motion of the sap, or that which circulates through the vessels of the plant, a connected series of rotations; or is it a continuous movement through the vascular tissues, forming the instrument of nutrition, and bearing analogy to a stream which diffuses fertility along the whole extent of its path? A question naturally offering itself for solution is, how the sap finds admission into vesicles awanting in apertures, or arrives at the interior of closed

vessels? The hard wood of a tree is composed of closely united longitudinal fibres, extending more or less spirally from the root to the summit; and such is the fine diminution to which they are reduced, that a single one, not larger than a hair, includes within it thousands of fibrillæ, or smaller vessels. The law regulating the ascent of sap in vessels so evasive, forms an inquiry which physiologists have divided into a variety of claims, arising from the action being excited by the stimulus of fluids, from a vital vermicular property, from the elastic force of generated gas, and from the several processes of transpiration, capillary attraction, and endosmose and exosmose.

The first mode seems to be prominently alleged by Darwin. (Phytologia, sect. iii. ii. 4.) "This circumstance," he says, "is confirmed by the evident proofs of the irritability of plants in various other instances, as the closing and opening of the petals and calyxes of flowers by light and darkness, warmth and cold, dryness and moisture, and by the motions of the leaves of the sensitive plant by any mechanical stimulus. To this might be added a variety of instances of the irritability of vegetables to the stimulus of heat, being increased after a previous exposure to cold, exactly in the same manner as happens to animal bodies, whence the reciprocal times of the acting and ceasing to act of these vernal vegetable absorbents, may be readily explained by their having been benumbed by cold, or excited into action by the warmth of the air or earth."

Dr. P. M. Rodget (Animal and Veget. Phys. vol. ii. pp. 19, 23) insinuates, that the progressive movement is produced by alternate contractions and dilations of the cells, referrible to the vitality of the organs; this seems, however, to be an assumption borrowed from animal circulation, where the impelling cause is a central organ.

According to Brücke, the specific gravity of the sap of the vine during spring hardly differs from that of water. Geiger and Proust showed that the sap contained much carbonic acid, and the gas so plentifully given off when any of the vessels are cut was conjectured to be of this kind.

Liebig is disposed to regard transpiration as the efficient cause of circulation. This effect takes place only when the weather is clear and dry; under a hygrometric depression, the juices are stagnated by surrounding moisture. But its progress, by tending to form a vacuum, is combined with atmospheric pressure, and a supply, therefore, is continued equivalent to the waste.

Draper, again, has suggested a capillary action, which he considers electrical, promoted by evaporation, as indicative of the mode by which fluids circulate in plants. The law by which a sponge, or piece of lump sugar, when partly dipped in liquid, becomes saturated at the free extremity, holds true of gases and all aqueous solutions, when brought into contact with the porous membrane of a vessel made up substantively of short capillary tubes. Accordingly, Dr. Walker proved the action of capillary siphons, by bending down a branch much lower than its origin from the tree, in which state the end was cut off in the bleeding season, when the sap flowed from its cut extremity, while no bleeding whatever took place from wounds on the trunk two or three feet lower than the origin of this branch. But that, however high capillary attraction may raise a fluid in minute tubes, it cannot make it flow over, is evident from this, that in a glass tube the fluid is left with a concave surface, not quite on a level with the upper rim. The constant loss, therefore, to which the vegetable fluid is submitted by being drawn off from above, acts like a suction power, and maintains, according to Draper, the principle of capillarity in continuous force.

Dutrochet (Memoires pour Servir à la Histoire Anatomique et Physiologique des Vegetaux et Animaux, Paris, 1837) has still further explained the circulation, by the strictly mechanical processes of imbibition and transudation, otherwise called endosmose and exosmose. The movement to which these give rise, always takes place between an interior fluid of different density, from another outside of a cell, both having an affinity for each other, and for the common membrane which separates them. The property of permeability to liquids is shared by the transverse membranes of cells when in contact; but it is obvious, it will also act through all the sides of vascular tissue when sufficiently tender and soft. Matteucci and Cima have both found this cause to be in active and universal operation among plants, and it is concerned in other motions beside that of the circulating sap, as in the opening of the seed vessels of Balsaam, Fig, Marigold, and Rose of Jericho, and in the spores and teeth of Horse-tail, Club-moss, &c. Dutrochet invented an Endosmometer, or measurer of the force of imbibition or endosmose. The instrument consisted of a glass tube doubly bent at unequal heights. The lower curvature is filled with mercury up to a certain point, the extended arm having a graduated scale attached. The opposite bell-like extremity is covered with bladder, to represent a vegetable membrane, and plunged into a jar of water. Sirup is introduced between the mercury and the bladder, by an opening at the higher curvature of the tube, which is secured by a plug. The effect on the mercury shows the force.

None of the above solutions, if taken separately, can entirely account for the phenomenon, and it is probably by a combined view of their operation that we are to arrive at an idea of it. In circulation, mechanical and chemical forces are at once united to produce an equilibrium of composition and decomposition, so as not only to move that on which they act, but to assimilate it to their own vitality.

That the passage of the sap is a vital action, is evident from the effects which follow its suspension, for when this action is finally stopped, the power to vegetate has ceased. This special study has been investigated by Malpighi, De la Baisse, Burnett, Thuret, and many others. A distinguished observer has exclaimed, "Who could ever actually see the sap of plants move in the vessels destined to its conveyance!" The minuteness of the vessels not only renders the anatomy of plants difficult of investigation, but, by their great rigidity, also incapable of receiving coloured injections. A variety of salts has been employed for this purpose, from a basis of copper, lead, zinc, iron, &c.; colouring matters have been also tried, and Darwin (Phytologia, sect. v. 4, 5) suggests that slowly calcined charcoal immersed in quicksilver, or even in melted coloured wax, as it so greedily absorbs all fluids when recently taken from the fire, or cooled without the contact of air, might produce beautiful vegetable preparations, and give more accurate light into the anatomy of plants. Strict details among the different classes remain, to a large extent, yet to be determined. De Candolle is of opinion that the sap reaches along the intercellular spaces; but while this may be true, it is generally believed to traverse the cells and vessels themselves. When an incision has been made in the growing stem of an Exogen, the juice oozed at first from the lower part of the wound, but a little later it escaped from the middle and upper sides also. The course of coloured solutions imbibed through the roots has been detected, first in the new wood, then in the leaves, and last of all in the bark. There is reason, in short, to think, that when the organs have been fully expanded, the sap finds its way up through the porous cells and vessels of the alburnum or new wood, percolating the interior of the stem through the cells of the medullary rays, until diffused over the upper, and then returned by the lower side of the leaf, it descends through the cells and vessels of the inner bark to the root, where it discharges the excreted matters remaining after elaboration of the sap into the various products of the plant.

With regard to the amount of circulation, it may be remarked generally, that while never stationary, it is under the varying subjection of the seasons. In spring, when

> "the juicy groves
> Put forth their buds, unfolding by degrees,"

the development of the growing points requires an unusual nursing, and the supply of sap inclines to them for the time being. Indeed, there is a gradual acceleration of sap both through summer and autumn, up to the development of the reproductive organs; and the actual measure not only increases as the periods of flowering or fruiting approach, but is accompanied by a corresponding consumption of the products which may have been already assimilated. This principle explains a number of familiar facts. It points out the first formation of the flower-bud as the fit time for collecting the juices of

plants either for food or medicine. Many trees in beautiful foliage, such as the ash, are sometimes seen to be barren; while prolific individuals are naked of leaves, from the quantity of sap expended on their flowers. The receptacle of the artichoke, in like manner, dries up previous to inflorescence; and the store of nutriment which enters into succulent tubers and roots, as Turnip and Carrot, is dissipated as the plants run to seed. The exhaustion consequent on flowering causes annual plants to die; but sap may be made to accumulate in that kind of plants, by breaking off the flower-buds as they form, which causes the stem to pass into that of an under-shrub, lasting for several years, as Tree-Mignionette. Perennial plants also are occasionally retarded in their flowering to the increase of nutritive juices; and it is commonly observed, that when, from climate or other causes, a deficiency in the flowering happens to fruit trees, their next produce is proportionate to the sap that has accumulated in the meantime. In perennials, where the flowering takes place after long intermissions, the vigour of the process is always remarkable by a vast display of flowers. On the other hand, a ring cut out in the bark, by collecting the ascending sap, will expedite the flowering, though to the serious interruption of the secreted products. When, at last, winter spreads his glooms, the ruin, which appears only to a thoughtless eye, is deprecated by the poet of the Seasons:—

> "The frost-concocted glebe
> Draws in abundant vegetable soul,
> And gathers vigour for the coming year."

Even in the midst of frost and snow, the sap does not entirely cease; for new fibres are then forming at the roots, and a slight enlargement of the buds takes place. (Henslow's Phys. Bot., p. 234.)

The organic force for diffusing the sap through a branching tree is very great. In the bleeding season, Hales attached a bent glass tube containing mercury to the stump of a vine, fastening it by means of a copper ring, carefully luted and covered with bladder, and on one occasion the sap raised the mercury upwards of 30 inches. In order to obtain a comparative result, he fixed glass tubes to the arteries of horses as near the heart as practicable, and found the blood in them to rise only 9 or 10 feet—an amount which presses with less than $\frac{1}{3}$ of the weight of the atmosphere, or about 4 lbs. on every square inch of surface; and as the surface of the left cavity of a horse may not exceed 30 square inches, its whole power does not equal the resistance of more than 120 lbs. But the ascent of sap is so many times greater than the blood of a horse, that when it rises 34 feet high, or equal the weight of the atmosphere, the column presses about 15 lbs. on every square inch of surface. A tree, therefore, 34 feet high, requires a pressure of 15 lbs. upon every square inch in the section of the vessels of the bottom, merely to support the sap. Now, if the mouth of a vegetable absorbent be considered in its area, as only $\frac{1}{10,000}$th part of the area of a square inch, the ten thousandth part of 15 lbs. is all that presses outwardly on each absorbent mouth; and its minute diameter and rigid sides contribute to avert a rupture from so high a column of interior sap juice. Nor is a continuation of this function the least interesting part. Boucherie found that a felled poplar, 92 feet high, immediately immersed in a solution of pyrolignite of iron, absorbed in six days to the amount of nearly 66 gallons. With a capacity like this, the propelling power upwards, to supply the constant evaporation which takes place, must be truly immense. And if such be the force which comes into play with every individual tree, who can calculate the united amount which inspirits the outbursts of vernal life?

> "Hail, Source of being! to Thee my thoughts
> Continual climb; who with a master-hand
> Hast the great whole into perfection touch'd.
> By Thee the various vegetative tribes,
> Wrapt in a filmy net, and clad with leaves,
> Draw the live ether and imbibe the dew.
> By Thee dispos'd into congenial soils,
> Stands each attractive plant, and sucks and swells
> The juicy tide; a twining mass of tubes.
> At thy command the vernal sun awakes
> The torpid sap, detruded to the root
> By wintry winds; that now in fluent dance,
> And lively fermentation, mounting, spreads
> All this innumerous-colour'd scene of things."

In its upward course from the root, the sap undergoes various changes in its composition and density; but in the leaf, the comparatively raw fluid is exposed to atmospheric influences, which co-operate with the root, and complete the scheme of nutrition, by a concurrence of all the parts in the preparation, qualification, and conservation of the circulating ingredients. The function of the root fibres, in supplying liquid food from the soil, is associated with the function of the leaves in providing gaseous food from the atmosphere; and the operation of the one has its counterpart in the other. The contrivance is beautiful, of exposing so great an amount of surface to the influence of external agents, as the thousands of square feet of leaf contained in every tree, fanned by a ceaseless motion on the petiole or stalk. The surface of the leaves bears a much larger relation to the surface of the trunk of plants, than the air-cells of lungs or gills to the bodies of any animal. The exuberance of foliage, therefore, sufficiently indicates the importance of its bearings with the surrounding element. Among the vital alterations effected in the leaf, carbon and hydrogen are fixed, oxygen disengaged, and watery fluids absorbed and exhaled; and we will now treat these effects singly, under the action of air, light, heat, and moisture.

AERATION.

Atmospheric air, consisting chiefly of oxygen, unites a quantity of nitrogen in about the ratio of 1 to 4, together with carbonic acid, and aqueous vapour in about $\frac{1}{50}$th of the whole in weight. These proportions, in strict accuracy, are not invariable; their amount, consequently, is dissimilar in particular times and places. They exist, however, more in a state of mixture than combination, so that the distinctive properties of each component remains unchanged. The whole element is a grand creation, hung up as the "sea of glass like unto crystal," which the Apostle John saw in vision: it bathes the globe in an aerial ocean, and arches outwards in sensibly lessening degrees for many miles.

Air is essential to vegetation, and there is no known instance of exception to this rule. In leafless plants, it is probable the entire surface acts the part of these appendages; and that portion of air which is contained in the soil or in water, suffices for the races which vegetate beneath their surface. Boerhaave asserted the maxim, that confined air, incapable of being renewed, is noxious to the plants subjected to its influence. "In vitris accurate clausis," says he, "licet tepore foto fœtus semina plantarum vitæ macerata, optimæ commissa terræ atque requisito excitata calore, non tamen crescunt, neque dant vitæ ulla signa actuosæ." The truth of this opinion, if not immediately, is ultimately placed beyond question. Duhamel observed, that land seeds die, if wholly immersed in water, from the necessity of being partially exposed to air in order to germinate; and Spallanzani found that, when so exposed, a humid pellicle of transpired matter appeared on the edge, which in close vessels of small dimensions containing little air was reabsorbed, and led to corruption. The latter naturalist also found that, when tested within an exhausted air-pump, seeds partially budded and branched, but the extent was altogether regulated by the capacity of the vessel; and when the vacuum was perfect, the germination was entirely averted.

The same results may be regarded as having been established by the negative effects which attend the contamination of atmospheric air, the balanced proportions of which, when displaced or deteriorated, are followed by injurious effects. According to Scheele, nitrogen, when gaseously administered alone to plants, leaves a foul air; and Priestly, Percival, and Saussure have shown, that hydrogen gas and carbonic acid gas, which could not be breathed by animals with impunity, will support vegetable life, but only temporarily, without the presence of free oxygen. Turner and Christison (Edin. Med. and Surg. Journal, xxviii. 356) have proved that sulphurous acid gas, hydrochloric gas, chlorine gas, and nitrous acid gas, disorganize the tissue of plants; while sulphuretted hydrogen, cyanogen, carbonic, oxide, and ammoniacal gases, act each as narcotic poisons, enervating and decaying the entire structure. Mr. N. B. Ward, surgeon in London, has invented portable conservatories or glass cases which protect growing plants from the vitiated

gases abounding in towns and near public works. In a strong box lined with zinc or lead, a composition is placed, representing a natural fertile soil, well moistened loam underlaid by a thin substratum of turf, and this resting on a stratum of gravel or broken earthenware. A closely-fitting glazed framework completes the apparatus. When the moisture of the plot of soil is vaporized, it is condensed on the inside of the framework, and trickles back again; while the respiration and decomposition of this watering nourish the plants as within a little world of their own. Of a small size, the case is unfavourable to flowering exogens; but lofty cases are fitted for nearly every species of greenhouse plant. Besides the ornamental purposes which they serve, they are useful for the conveyance of exotics under extreme temperatures.—(See Ward on the Growth of Plants in closed cases.)

The aeration of leaves is a composite function, embracing both a mechanical and chemical part. We may be allowed to suggest whether the pressure of the atmosphere on the principle of affecting rotation or circulation, may not graduate vegetation in its ascending belts, by adjusting the tissues of particular tribes to degrees of altitude? If we have reason to apprehend that circulation is most sluggish at the lowest temperature, does it so appear in races indigenous to the greatest heights? Does, in short, the increased or diminished pressure of air adapt itself to a scale of vegetation; or regulate every stage of a vertical line from the surface of the earth where air is densest, zoning them with appropriate races, up to the highest territorial altitude, where the lichen clings to its frozen crags? We know, at least, that the gentlest plant grows up in the midst of the air, as under an invisible mantle; and yet, so mobile is it, that though the downiest seed sailing through it, may wave it with its wings, its gentlest agitation braces the piny children of the Alps, and its rugged blasts sweep away the oak like a snow-flake from the plain. Over the whole compass of vegetation, it is suspended like a speckled screen; and chastens the panorama of the sun with the dissolving blue of morn, the bright white of noon, and with chariots of clouds that gather at the evening setting. Bryant, in his finished production, entitled "The Evening Wind," pleasingly apostrophizes its motions, as "God's blessing breathed upon the fainting earth."

"Go, rock the little wood-bird in his nest,
  Curl the still waters, bright with stars, and rouse
The wide old wood from his majestic rest,
  Summoning, from the innumerable boughs,
The strange deep harmonies that haunt his breast.
  Pleasant shall be thy way, where meekly bows
The shutting flower, and darkling waters pass,
And where the o'ershadowing branches sweep the grass."

The chemical play of air in the leaves is conducted chiefly through the organisms, known as stomata, or breathing pores. The stomata, interspersed upon other less absorbent parts of a plant, probably exercise an auxiliary function in the aeration. The spiral vessels have been sometimes alleged to be tracheæ, or true windpipes, conveying air to and from the stomata; but there does not seem to be any immediate connection between them and the horizontal perforations of the cuticle; and it is certain, that the leaf is endowed with an independent access to the air. It has been also proved of the air vessels, as they are called, that they contain aeriform matters; and, in some cases at least, the air they contain has, from whatever chemical changes, been found to consist of a larger proportion of oxygen than atmospheric air. Upon the whole, it is doubtful whether the action of these vessels be more than local. There are cells, too, or microscopic cavities, of beautiful appearance, which contain air both in the leaves, stem, or other parts. In plants which do not float, they assume the appearance of a lacerated cellular mass: such are the chambers in the pith of the Walnut tree, and the tubular cavities in the stem of the Bamboo and other grasses. Floating plants contain sensible quantities of air, as Pontederads, Caltrops, and Fucoids. In Vallisneria, the air cells, when examined, appear as dark lines; if cut under water, the contents escape in the form of bubbles for a considerable time; and two leaves adjusted to the light, have been known to yield an ounce of air in six days. These cases prove that the air taken up in the cells of aquatics must have been absorbed by the water; but, in the same manner, the superficial parts of the soil absorb it as essential to germination; and the following table from M. Petri, whose experiments were made on turnip seed, shows the decrease in germination to be proportionate to exclusion from the air:—

Seed sown to the depth of	Came above ground in	Number of plants that germinated.
½ inch.	11 days.	7-8ths.
1 "	12 "	All.
2 "	18 "	7-8ths.
3 "	20 "	6-8ths.
4 "	21 "	4-8ths.
5 "	22 "	3-8ths.
6 "	23 "	1-8th.

One inch for such seeds is the proper depth in sowing.

In 1771, Priestly ascertained, by experiment, that when immersed in a measure of carbonic acid gas, which consists of oxygen and carbon, plants absorbed the carbon, and left the oxygen free. A good deal of obscurity long enveloped this particular; but something like certain conclusions may now be regarded as established by the best experimenters. The compounds in air, as pure air to be inhaled, are indispensable to all animals, in proportion to their diversity of habitude; but it is oxygen almost solely that the higher animals extract in inspiration, and its carbonic acid, which would be deleterious to their life and nourishment, is discharged in respiration. Now, the carbon thus emitted by animals is precisely that which constitutes the main nourishment of plants, so far as air is concerned; in absorbing air, therefore, plants appropriate carbon, and restore oxygen to the atmosphere, and are always co-operating inversely with animals to maintain it in its natural composition. This is the general action of air in plants; but its constituents admit of separate combinations with their specific materials, converting the juices into a sap from which all the secretions are formed.

The air contains, of carbonic acid, only about 1 gallon in 2,500; and the proportion of carbon taken by plants, is modified by the nature of the soil and plant, the climate and seasons; but in the British islands, the crops raised from land of average fertility, are ascertained to derive no less than from $\frac{1}{3}$ to $\frac{4}{5}$ths of the entire quantity of their carbon from the air. "By the conjoined labours of millions of pores," says Johnstone (Elem. of Agr. Chem. and Geol., chap. iii., sect. 1), "the substance of whole forests of solid wood is slowly extracted from the fleeting winds. The green stem of the young shoot, and the green stalks of the grasses, also absorb carbonic acid, as the green of the leaf does, and thus a larger supply is afforded when the growth is most rapid, or when the short life of the annual plant demands much nourishment within a limited time."

We should now, in course, proceed to the consideration of light, heat, and moisture; but these are too momentous topics to be lightly taken up. We shall, therefore, content ourselves with a simple enumeration of the conclusions which obviously arise out of the whole subject:—

1. The opening and closing of flowers.
2. Growth of parasites and air plants.
3. Wide culture and ventilation, applied to pruning and thinning.
4. Forcing and its limits.
5. Felling, barking, and gathering.
6. Draining.

COMPENDIUM OF LOGIC.

CHAPTER VI.

PART III. CONTINUED—DIVISION OF SYLLOGISMS ACCORDING TO MOOD AND FIGURE—REDUCTION OF SYLLOGISMS.

We have seen that logic is divided into three parts, the Term, Proposition, and Syllogism, each of these being the verbal expression of those operations, or acts of the mind, which are termed respectively, Perception, Judgment, and Reasoning. We have now discussed the Term and the Proposition, and in last chapter we commenced the discussion of the Syllogism,

first, by explaining its different parts, and then by a statement of the principal rules on which its validity depends. We enumerated also its divisions according to the nature of the question to be proved, or that of the conclusion deduced, which we explained as corresponding to those of the four kinds of propositions respectively denoted by the letters, A, E, I, O. We stated that a syllogism is characterized by one or other of these letters, according to the quantity and quality of the proposition of which its conclusion consists. But there is another division of the syllogism, which, as it embraces the preceding, and something more, may be regarded as superseding it. We therefore proceed to consider, in the next place—

THE DIVISION OF THE SYLLOGISM INTO MOODS.

The mood of a syllogism signifies the quantity and quality, not of the conclusion only, but of each of the three propositions of which the syllogism consists. As the quantity and quality of propositions are denoted by the letters above mentioned, and as these will play a very important part in the present chapter, it may be convenient for the reader's reference to reproduce, in this place, the following scheme, which was given on a former occasion, premising, that in *quantity* a proposition is either Universal or Particular; in *quality*, either Affirmative or Negative:—

Symbols of the Quantity and Quality of Propositions.	Examples.
A (Universal Affirmative),......	All planets are inhabited.
E (Universal Negative),.........	No planets are inhabited.
I (Particular Affirmative),......	Some planets are inhabited.
O (Particular Negative),........	Some planets are not inhabited.

Now, in expressing the mood of a syllogism, those three letters are employed which indicate the quantity and quality of each of its three propositions, stated in the order in which they stand. Thus, in the following syllogism—

(A)...........All kings are immortalized;
(I)............Some weak men are kings; therefore,
(I)............Some weak men are immortalized;

the propositions are respectively denoted by the letters A, I, I. These letters, therefore, denote the mood of the syllogism. So in the following example:—

(E)...........No tyrant is happy;
(I)............Some monarchs are tyrants; therefore,
(O)...........Some monarchs are not happy.

Here, the major premiss is E (universal negative); the minor, I (particular affirmative); the conclusion, O (particular negative); therefore, the mood of the syllogism is E, I, O.

Now, as there are four kinds of propositions, respectively denoted by the letters A, E, I, O, and three propositions in each syllogism, the number of possible moods will correspond to all the possible ways of combining these four letters by threes. This, by a simple computation, may be shown to amount to sixty-four; for any one of these four propositions may be the major premiss; and each of these four majors may have four different minors; this will give sixteen pairs of premisses, each of which may have four different conclusions, amounting in the whole to sixty-four different syllogisms, all of which may be formed by different combinations of three terms thrown into triplets of propositions varying in quantity and quality.

But all of these combinations, though possible, are not admissible in practice, from violating some of the logical rules which we explained at the end of the preceding chapter. For example, the moods I, I, I, I, O, O, and O, O, O, must be rejected, from each having two *particular* premisses, and thereby violating Rule VII., in which it is shown that from two particular premisses nothing can be proved. In like manner E, E, E must be rejected, as violating Rule III., which shows that the same result follows when both premisses are *negative.* So also, I, E, O, for an *illicit process* of the *major* term, as explained under Rule II. Thus, by examining all the combinations, and comparing them respectively with these rules, it is found that a great majority are useless, and that, of the whole sixty-four, there remain but eleven moods which can be used with propriety in a legitimate syllogism, viz.:—

(The Eleven Practicable Moods.)

A, A, A.	A, I, I.	E, I, O.
A, A, I.	A, O, O.	I, A, I.
A, E, E.	E, A, E.	O, A, O.
A, E, O.	E, A, O.	

DIVISION OF THE SYLLOGISM ACCORDING TO FIGURE.

Another division of the syllogism is according to figure. This consists in the situation of the middle term with respect to the major and minor terms, which, as previously defined, are the predicate and subject of the conclusion. This admits of four arrangements, termed respectively the First, Second, Third, and Fourth Figures, as follows:—

First Figure—When the middle term is made the *subject* of the *major* premiss, and the *predicate* of the *minor.*

Second Figure—When the middle term is the *predicate* of *both* premisses.

Third Figure—When the middle term is the *subject* of *both* premisses.

Fourth Figure—When the middle term is the *predicate* of the *major* premiss, and the *subject* of the *minor.*

The *first* of these figures is the simplest and most natural; it is that alone to which the Dictum of Aristotle can be *directly* applied; and, therefore, the examples previously adduced have chiefly been confined to syllogisms in this figure. But rules will be afterwards given for reducing all the other figures to this form.

The *fourth* figure is exactly the reverse of the *first;* it is the most unnatural and awkward of all, and on that account is rarely used in argument.

The following scheme of the different figures will show, at a glance, the disposition of the middle term in each, assuming

For the Major term, M; Minor, N; Middle, x.

1st Fig.	2d Fig.	3d Fig.	4th Fig.
x, M,	M, x,	x, M,	M, x,
N, x,	N, x,	x, N,	x, N,
N, M.	N, M.	N, M.	N, M.

DIVISION OF SYLLOGISMS BY MOOD AND FIGURE COMBINED.

The reader will readily perceive that neither the mood alone nor the figure alone determines the exact form of the syllogism. Thus, in the first figure we may have different syllogisms, as follows:—

Syllogisms in the First Figure.

(1)	(2)	(3)
All x is M;	All x is M;	No x is M;
All N is x;	Some N is x;	Some N is x;
therefore,	therefore,	therefore,
All N is M.	Some N is M.	Some N is not M.

Other variations in quantity and quality might be given under the same figure, and so with each of the rest. Now, it will be seen that, in the first example, both the premisses and the conclusion are universal-affirmative; in the second example, the major premiss is universal-affirmative, the minor premiss and conclusion, particular-affirmative; in the third example, the major premiss is universal-negative, the minor particular-affirmative, the conclusion particular-negative. The first is, therefore, of the mood, A, A, A; the second, of the mood, A, I, I; the third of the mood, E, I, O; and all three are syllogisms in the first figure.

Thus it appears, that to determine the exact form of a syllogism, both the figure and mood must be assigned, and this will be sufficient for the purpose. Let it be proposed, for example, to construct a syllogism in the third figure, mood A, A, I; then, assuming the symbols of the three terms as before, we shall have the following form:—

$$\left.\begin{array}{l}\text{(A) All } x \text{ is M;}\\ \text{(A) All } x \text{ is N;}\\ \quad\text{therefore,}\\ \text{(I) Some N is M.}\end{array}\right\}\text{Syllogism in 3d Figure, Mood A, A, I.}$$

Or, substituting significant terms, "*Precious*" for the major term M; "*Mineral*" for the minor, N; and *Gold* for the middle,

x; then we have the following syllogism, both in form and signification:—

(A)............All gold is precious;
(A)............All gold is a mineral; therefore,
(I)............*Some* mineral is precious.

The terms being given, and the figure and mood assigned, any syllogism may be thus constructed.

Now, as we have shown that the allowable moods are *eleven* in number, it follows that, if all the allowable moods could be applied in each of the figures, the total number of distinctions in the syllogism, according to figure and mood, would be *forty-four*. It happens, however, that some of the moods, though allowable in one or more of the figures, are not allowable in all, as the mood which is allowable in one figure may, in another, violate some of the logical rules to which we have already referred. Thus, the mood A, A, A, though allowable in the first figure, cannot be allowed in the second, in which it will be seen from the scheme that the middle term (x) is the predicate in both premisses, and would, therefore, be distributed in neither, if both were affirmative. This second figure, therefore, rejects not only A A A, but A A I, A I I, and I A I, all of which have two affirmative premisses, and would not in that figure *once distribute* the middle. So I A I is an allowable mood in the third figure, but in the first it would have an undistributed middle. A E E is an allowable mood in the second figure, but in the first it would produce an *illicit process* of the major term. These results are inadmissible, involving positive fallacies by violating certain logical rules; but some combinations of mood and figure are rejected as giving only particular conclusions when a universal might be drawn. For example, E, A, O, in the first figure:—

(E)............No mammals are fishes;
(A)............All whales are mammals; therefore, by
(O)............*Some* whales are not fishes.

—a conclusion perfectly true indeed, but useless, because it is superseded by E, A, E in the same figure, from which we infer the *universal*—that "*no* whales are fishes."

By rejecting those combinations which violate the logical rules, it is found that each of the figures admits only six of the moods; and thus, of the whole forty-four combinations, only *twenty-four* can be framed which admit of valid conclusions. But, again, of these twenty-four, five are rejected as useless, because superseded by some of the others; and thus only nineteen remain which admit of application in practice. All the forms of the syllogism, therefore, capable of yielding *valid* and *useful* conclusions, and which may be distinguished by mood and figure combined, are *nineteen* in number. These are distributed in each figure as follows:—

Fig. 1,......A A A, E A E, A I I, E I O,........................ 4
Fig. 2,......E A E, A E E, E I O, A O O,........................ 4
Fig. 3,......A A I, I A I, A I I, E A O, O A O, E I O,......... 6
Fig. 4,......A A I, A E E, I A I, E A O, E I O,.................. 5

Total, ...19

By examining the above scheme, it will be seen that A E O, one of the eleven allowable moods, does not occur in any of the figures, being, in fact, superseded by A E E, which occurs in the second and fourth. Only ten moods, therefore, occur, and these, as the reader will observe, are distributed among the figures as follows:—

Moods.	1st Fig.	2d Fig.	3d Fig.	4th Fig.
A A A,	1	0	0	0
A A I,	0	0	1	1
A E E,	0	1	0	1
A I I,	1	0	1	0
A O O,	0	1	0	0
E A E,	1	1	0	0
E A O,	0	0	1	1
E I O,	1	1	1	1
I A I,	0	0	1	1
O A O,	0	0	1	0
	4	4	6	5

From this table it will be observed that A A A occurs only in the first figure, and O A O in the fourth. E I O admits of legitimate application to every one of the figures. All the others occur in only two of the figures.

These are matters of greater curiosity than value, and therefore, overlooking the above table, let us recur to the preceding list of the different available moods in each of the four figures. From that list, the reader will perceive that the letters representing the *conclusions* of the four moods in the first figure are respectively A, E, I, O; and that, therefore, every kind of proposition may be proved under this figure; that the second figure proves only negatives, E and O; the third figure only particulars, I and O; the fourth figure, I, E, and O, or all but universal affirmatives (A), which can only be proved by the first figure, and only by a mood in which the premisses are both universal-affirmative.

To the student who aims at proficiency in logic as an *art*, it is of importance that he should retain in his mind the available moods in each figure; and to render it easier to do so, the worthy logicians of the schools devised the following mnemonic lines, consisting of a number of barbarous words, in which the *vowels* will be found to correspond to the different moods appertaining to each of the figures, as given in the list above referred to:—

Fig. 1,....*Barbara*, *Celarent*, *Darii*, *Ferio*-**que prioris.**
Fig. 2,....*Cesare*, *Camestres*, *Festino*, *Baroko*, **secundæ.**
Fig. 3, { **Tertia,** *Darapti*, *Disamis*, *Datisi*, *Felapton*.
Bokardo, *Feriso*, **habet: quarta insuper addit.** }
Fig. 4,....*Bramantip*, *Camenes*, *Dimaris*, *Fesapo*, *Fresison*.

The words which we have marked by distinguishing type, as *prioris*, *secundæ*, &c. indicate the order or number of the figure to which the corresponding moods belong, and serve, moreover, to make up the Latin hexameters of which the verses consist. The other words *Barbara*, *Celarent*, &c. are mere artificial combinations of letters, in which the vowels represent the moods, A A A, E A E, &c., previously enumerated under a simpler form. The addition of the consonants, however, so as to form a resemblance of words, with the rhythm of hexameter verses, not only enables the learner the better to commit them to memory, but serves also another purpose, the nature of which we shall explain when we come to the subject of *reducing* the moods from one figure to another.

To the general reader, who studies logic as a *science* merely with a view to understand the principles of reasoning, and not to acquire a scholastic dexterity in *wrangling*, we frankly admit that even the very small labour of committing these verses to memory will scarcely be compensated in practice by any equivalent advantage. It is, however, curious and instructive to peruse them, with a knowledge of their meaning and application, as a monument of that medieval ingenuity, which was, we may truly say, worse than wasted, in weaving an interminable cobweb of frivolous subtleties. We shall, therefore, be satisfied with making a very few remarks on each of the figures in succession.

Moods in First Figure.—The characteristic of this figure is, that the middle term is the subject of the major premiss, and the predicate of the minor. It possesses the peculiar advantage that, being the most natural and simple, Aristotle's Dictum may be applied to it directly, and that all sorts of questions or conclusions may be proved by it, whether A, E, I, or O; *i. e.*, whether universal or particular, affirmative or negative. Its moods are four, *Barbara*, *Celarent*, *Darii*, *Ferio*, all of which are so generally employed that we shall give one example in each:—

Figure I.—Mood *Barbara*.

bAr..............*Every wicked man* is miserable;
bA...............All tyrants are *wicked men*; therefore,
rA...............All tyrants are miserable (A).

Mood *Celarent*.

cE...............*He that is always in fear* is not happy;
lA...............Covetous men are *always in fear*; therefore,
rEnt.............Covetous men are not happy (E).

Mood *Darii*.

dA...............*Whatsoever tends to our welfare* is good for us;
rI...............Some afflictions *tend to our welfare*; therefore,
I................Some afflictions are good for us (I).

Mood *Ferio.*

fE..............*Nothing that is hurtful* is desirable;
rI..............Some pleasures are *hurtful;* therefore,
O..............There are some pleasures not desirable (O).

It will be observed, that in this figure the major proposition must always be universal, and the minor affirmative.

Moods in Second Figure.—In this figure the middle term is the *predicate* of both premisses. Hence it can prove only *negative* conclusions; for the conclusion can only be affirmative when *both* the premisses are so; but in this figure *one* of them must always be negative, otherwise the middle term, being the predicate in both, would not be distributed *once.* The number of moods in this figure is likewise four—*Cesare, Camestres, Festino, Baroko*—of which the following are examples:—

Figure II.—Mood *Cesare.*

cEs..............No deceiver is *fit to be trusted;*
A..............Every good Christian is *fit to be trusted;* therefore,
rE..............No good Christian is a deceiver.

Mood *Camestres.*

cAm..............Good policy *attains permanent benefits;*
Es..............No knavery *does so;* therefore,
trEs..............No knavery is good policy.

Mood *Festino.*

fEs..............Nothing is good which *leads to ultimate evil;*
tI..............Some acts of beneficence *do so;* therefore,
nO..............Some beneficent acts are not good.

Mood *Baroko.*

bA..............All the truly noble are *virtuous;*
rOk..............Some who are styled noble are not *virtuous;* therefore,
O..............Some called noble are not truly so.

It will be observed, that in this figure the major premiss is always universal, and the minor premiss, together with the conclusion, negative. Whately remarks that "when we have to *disprove* something that has been maintained, or is likely to be believed, our arguments will usually be found to take most conveniently the form of the second figure."

Moods in Third Figure.—In this figure the middle term is the *subject* of both premisses; the minor premiss (as in the first figure) is always affirmative; the conclusion is always particular. This figure, therefore, cannot be employed to prove a universal proposition. The reason of this is obvious: both the major and minor terms are the predicates of their respective premisses, the middle term being the subject of both; hence, if both are affirmative, neither the major nor minor term is distributed, and, therefore, the conclusion must be particular. But if one of the premisses be negative, then the conclusion must be negative, and, therefore, will distribute its predicate, the major term. This must, therefore, be distributed in the major premiss. But being the predicate of that premiss, the proposition must be negative, otherwise its predicate would not be distributed. Therefore, the major premiss being negative, it follows that the minor premiss is affirmative, for nothing can be proved from two negative premisses. The minor premiss, therefore, will not distribute its predicate, the minor term, which, being the subject of the conclusion, makes the conclusion particular in this case also.

The third figure has six moods—*Darapti, Disamis, Datisi, Felapton, Bokardo, Feriso*—of which the following are examples:—

Figure III.—Mood *Darapti.*

dA..............*Whosoever believes* shall be saved;
rAp..............*All believers* have their imperfections;
tI..............Some who have imperfections shall be saved.

Mood *Disamis.*

dIs..............*Some valorous achievements* are useless;
Am..............*All valorous achievements* are applauded;
Is..............Some things applauded are useless.

Mood *Datisi.*

dA..............*All valorous achievements* are applauded;
tIs..............*Some valorous achievements* are useless;
I..............Some useless deeds are applauded.

Mood *Felapton.*

fE..............*No cowardice* is honourable;
lAp..............*All cowardice* is selfish prudence;
tOn..............Some selfish prudence is not honourable.

Mood *Bokardo.*

bOk..............*Some great thinkers* are bad writers;
Ar..............*All great thinkers* teach wisdom;
dO..............Some who teach wisdom are bad writers.

Mood *Ferison.*

fE..............*No wise man* pursues a phantom;
rIs..............*Some wise men* pursue fame;
On..............Some who pursue fame do not pursue a phantom.

Moods in Fourth Figure.—This figure, as Whately justly remarks, is "never employed but by an accidental awkwardness of expression." Being exactly the reverse of the first, as regards the arrangement of the middle term, it is the most awkward of all the figures, and draws its conclusion so indirectly that there is no advantage, but great inconvenience in using it. Some logicians, indeed, will allow it to be nothing but a mere inversion of the first. It is, however, certainly entitled to be reckoned a separate figure; and cannot, like the first, be employed to prove a universal-affirmative, A, though it proves all the other three conclusions, viz. E, I, O. It has five moods, *Bramantip, Camenes, Dimaris, Fesapo, Fresison,* of which examples are subjoined:—

Figure IV.—Mood *Bramantip.*

brAm..............All diamonds are *pure carbon;*
An..............*All pure carbon* is combustible;
tIp..............Something combustible is the diamond.

Mood *Camenes.*

cAm..............All miracles are *violations of the laws of Nature;*
E..............*No violations of Nature's laws* are easily credited;
nEs..............Nothing easily credited is a miracle.

Mood *Dimaris.*

dIm..............Some mysteries are *believed by Christians;*
A..............*All that is believed by Christians* is credible;
rIs..............Some credible things are mysterious.

Mood *Fesapo.*

fEs..............No immoral acts are *lawful amusements;*
A..............*All lawful amusements* are sources of enjoyment;
pO..............Some sources of enjoyment are not immoral acts.

Mood *Fresison.*

frEs..............No philosophers are *fools;*
Is..............*Some fools* utter wise sayings;
On..............Some who utter wise sayings are not philosophers.

The learner will naturally inquire how it happens that A, or universal-affirmative conclusions, cannot be proved by this figure. The question is of little importance in a practical view; for all that can be proved by the figure can be much more clearly and directly proved by the first, *and universal-affirmatives also.* But still it is not less curious than instructive, as a mere theoretical question involved in the *science* of logic, to examine the principles which limit the utility of what are called the three *imperfect figures,* namely the second, third, and fourth. We have, therefore, explained how the second proves only *negative* conclusions; the third only *particulars;* and now we must request the reader to observe how it may be shown by a similar *demonstrative* process, that the fourth figure *cannot* be employed to prove universal-affirmatives.

The middle term is, in this figure, the predicate of the major premiss and the subject of the minor, thus—

Major, *middle.*
middle, Minor.
Minor, Major.

Now, if the conclusion were universal (whether affirmative or negative), the minor term would be distributed, being the subject of the conclusion. It must, therefore, be distributed also in the minor premiss (Rule II.); but, being the *predicate* of that premiss, it cannot (as a general rule) be distributed, unless the proposition be negative. The minor premiss must,

therefore, be negative to give a *universal* conclusion; and if one of the premisses be negative, so must the conclusion likewise. (Rule V.) Hence, it is impossible in this figure to have the conclusion *universal*, and at the same time *affirmative*, *i. e.*, *universal-affirmative*.

And here it may be proper to guard the reader against a mistake which is apt to arise with regard to the figure of a syllogism, from the transposition of the premisses. From this cause, the first may be mistaken for the fourth, as when we say:—

The English are *a free people*;
A free people are happy;
Therefore, the English are happy.

This has the appearance, at first sight, of belonging to the fourth figure, the middle term standing in the *first* premiss as the predicate, while it is the subject in the *second;* and this, as the reader is aware, is the arrangement in the fourth figure. The conclusion, however, is A, or universal-affirmative, which can be obtained by the first figure only; a mystery which a closer inspection will explain, by showing that the premisses are here transposed, or varied from the common arrangement, the minor premiss being put as the first proposition instead of the major. This transposition does not affect the conclusion or alter the figure of the syllogism, though it is the natural and common arrangement to place the major premiss (or general principle) first; but this premiss, whether placed first or second, may always be known by its containing the major term, *i. e.* the predicate of the conclusion—the minor premiss, on the contrary, containing the minor term, *i. e.* the subject of the conclusion.

Now, in the preceding example, the predicate of the conclusion (or major term) is *happy;* the subject of the conclusion (or minor term) is *the English.* The premisses containing these terms are, therefore, respectively the major and minor premisses; and the middle term, *a free people*, is really the subject of the major and the predicate of the minor premiss. In other words, the syllogism is in the *first* figure, and, stated in the common form, would stand thus:—

A free people are happy;
The English are *a free people;*
Therefore, the English are happy.

A similar resemblance does not exist between any other two figures, even when the premisses are so transposed; and, therefore, we need not enlarge any further on this subject. At present we only desire to impress on the learner the necessity of exercising caution in distinguishing the major from the minor premiss, whichever of the two may be placed first.

REDUCTION OF SYLLOGISMS.

As all kinds of questions or conclusions may be proved by the first figure, to which alone Aristotle's Dictum can be directly applied, it becomes of importance to inquire whether the process of reasoning employed in the other three figures be really the same as in the first, and whether, by a strictly logical *conversion*, it may not be reduced to precisely the same form. This conversion of the different moods in the second, third, and fourth figures, to one or other of the moods in the first, can really be performed in all cases; and syllogisms so converted, are said to be *reduced to the first figure*, or simply *reduced.*

This *reduction* is of two kinds—either direct or indirect. The first is termed Ostensive Reduction, the second *Reductio ad absurdum*, or *ad impossibile.* In proceeding to explain each of these methods, we may remark that the four moods in the first figure, *Barbara, Celarent, Darii, Ferio*, are termed the *perfect* moods; the others, *imperfect.*

1. *Direct or Ostensive Reduction.*—The process of reducing the imperfect to the perfect moods is so called, when, from either the transposition or illative conversion of the premisses contained in a syllogism of the imperfect mood, we gain one which yields the same conclusion in a perfect mood, or one from which that conclusion follows by illative conversion.

Thus, to show how *Darapti*, a mood in the third figure, may be converted into *Darii*, let us take our former example of the mood *Darapti:*—

dA..............*Whosoever believes* shall be saved;
rAp.............*All believers* have their imperfections;
tI...............Some who have imperfections shall be saved.

Here it is sufficient to *convert* the minor premiss by *limitation* (or *per accidens*), and then we have a syllogism in the first figure, yielding, with virtually the same premisses, the same conclusion:—

dA..............*Whosoever believes* shall be saved;
rI................Some who have their imperfections are *believers;*
I..................Some who have imperfections shall be saved.

In like manner *Cesare*, a mood in the second figure, may be reduced to *Celarent* by *simple* conversion of the major premiss:—

Cesare, Fig. II., reduced to	*Celarent.*
No impostor is *trustworthy;*	*No trustworthy man* is an impostor;
Every good Christian is *trustworthy;*	Every good Christian is *trustworthy;*
No good Christian is an impostor.	No good Christian is an impostor.

In this case the *simple* conversion of the *major* amounts to *illative* (or *inferential*) conversion, for, the proposition being E (universal-negative), both its terms are distributed.

In neither of the preceding examples do we require to *transpose* the premisses, but merely to *convert* one of them, while we arrive at a conclusion precisely the same as the original. In other cases, however, we must follow a more circuitous route. Let it be required, for example, to reduce *Camestres* to *Celarent:*—

cAm............All virtue is *amiable;*
Es...............No cunning is *amiable;* therefore,
trEs............No cunning is a virtue.

To reduce this to *Celarent*, the minor premiss must be converted, the premisses transposed, and then the conclusion converted. Thus, by the first two operations, we obtain the following:—

cE...............There is *nothing amiable* in cunning;
lA...............All virtue is *amiable;* therefore,
rEnt.............There is no virtue in cunning.

Here we arrive at a conclusion, not, indeed, exactly the same as that of the original syllogism, but of exactly the same import, for if "there is no virtue in cunning," it follows, by illative conversion, that "no cunning is a virtue."

In explaining the *conversion of Propositions* (Chap. V.) we mentioned conversion by negation, or by contraposition, which furnishes another method of ostensively reducing some of the imperfect moods to the first figure. Thus, *Baroko* may be reduced to *Ferio:*—

bA...............All the gases are permanently elastic;
rOk.............Some aëriform bodies are not permanently elastic.
O.................Some aëriform bodies are not gases.

Here, by converting the major premiss by negation (or contraposition) we obtain the following in *Ferio:*—

fE...............*Bodies not-permanently-elastic* are not gases;
rI................Some aëriform bodies are *not-permanently-elastic;*
O................Some aëriform bodies are not gases.

In this case the negation is joined to the predicate of what is the major premiss in the original syllogism; and thus the predicate of the minor premiss in *Ferio*, *not-permanently-elastic* (which is the middle term), must be regarded as affirmative to constitute a proposition in I.

Bokardo also may thus be reduced to *Darii*, converting the major by negation, and then transposing the premisses. In this case the conclusion will be the *converse by negation* of the original one, which may, therefore, be inferred from it. The reader may exercise his logical skill in trying this species of *reduction* upon the example of *Bokardo* given under Figure III.

2. *Indirect Reduction (Reductio ad impossibile*, or *ad absurdum).*—This method consists in proving, by the first figure, not *directly* that the original conclusion is true, but that it cannot be false, or that an absurdity would be the result of supposing it untrue. For this purpose we take the *contradictory* of the conclusion, which must be true if the conclusion is false; and substituting this for one of the premisses, we show that an absurdity follows, or that the new conclusion will contradict

the other premiss, and must, therefore, be false. Thus, let us take the following example in *Ferison*, Fig. III.:—

fE..............*No wise man* pursues a phantom;
rIs..............*Some wise men* pursue fame;
On..............Some who pursue fame do not pursue a phantom.

Now, if this conclusion be false, its *contradictory* must be true; viz.:—

All who pursue fame pursue a phantom.

Let this proposition, therefore, be substituted for the major premiss, and then we have the following syllogism in Fig. I.:—

dA..............*All who pursue fame* pursue a phantom
rI..............Some wise men *pursue fame;*
I..............*Some wise men pursue a phantom.*

Here it will be seen that our new conclusion stands in direct contradictory opposition to the original major premiss:—

No wise man pursues a phantom.

One of the two must, therefore, be false. But the premisses are always supposed to be granted, and, therefore, the falsity must be in the new conclusion. This conclusion, however, is validly inferred from its premisses by one of the perfect moods, in accordance with Aristotle's Dictum. One or both of these premisses must, therefore, be false. But the minor premiss is one of those originally granted, and must, therefore, be assumed as true. Hence it is the major premiss that must be false; and this being the contradictory of the original conclusion, *that conclusion must be true.*—This affords a good example of the *reductio ad absurdum*, or indirect mode of reasoning.

This kind of reduction is, however, seldom employed except for *Baroko* and *Bokardo*, which cannot be otherwise reduced except by conversion by negation (or contraposition). It is, therefore, adopted for these moods by those who reject this latter method, and confine themselves to *simple* conversion or conversion *by limitation.* The method of conversion by contraposition is, however, quite legitimate, and with its assistance *all* the imperfect moods may be ostensively reduced, that is to say, *directly.*

The consonants in the names of the moods.—The uses of the vowels, A, E, I, O, which occur in the names of the moods, have been already explained, and we are now in a position to explain the meaning of the consonants. These are so ingeniously framed, as to embody complete directions for *reducing ostensively* each of the imperfect moods to a mood in the first figure. With this view the following are the meanings of all the significant consonants:—

The initial letters B, C, D, F (with one or other of which the names of all the moods commence), indicate to which mood of the first figure (*Barbara, Celarent, Darii, Ferio*) each of the imperfect moods is directly reducible: *e. g. Cesare* to *Celarent; Festino* to *Ferio*, &c.

m (for *mutandis præmissis*) means that the premisses are to be transposed.

s and *p* are indications that the proposition denoted by the vowel *immediately preceding* is to be *converted*: *s, simpliciter* or simply; *p, per accidens*, or by limitation.

But *p*, in the mood *Bramantip*, stands for *particular*, and denotes that a *particular* conclusion is deduced, though the premisses warrant a *universal*, and do afford a *universal*, when reduced to the first figure.

k is the only letter which has reference to the indirect method of reduction *(ad impossibile).* It occurs only in *Baroko* and *Bokardo*, which, as we have seen, are the only moods that do not admit of *ostensive reduction*, except by negation or contraposition—a method which some logicians reject. In these cases, therefore, *k* is a sign that the proposition denoted by the vowel immediately preceding must be left out, and the *contradictory* of the conclusion substituted, viz., for the *minor* premiss in *Baroko*, and for the *major* in *Bokardo.*

But for those who adopt the method of conversion by negation, *k* may be assumed as the index of that kind of conversion; and then to indicate the method of reducing the two moods in question, the name of *Baroko* may be changed to *Fakoro*, and that of *Bokardo* to *Dokamo*—the former being now reduced to *Ferio*, the latter to *Darii*, instead of being both reduced to *Barbara*, as by the indirect method.

It will be observed that *r*, and some other consonants occurring in the names of the moods (especially of those in the first figure), are added merely for euphony.

The uses of all the significant consonants, as above explained, are briefly stated in the following mnemonic lines, which constitute a key to the lines enumerating the names of the moods:—

Barbara demonstrat B; *Celarent* C reducit;
D redit ad *Darii;* F redit ad *Ferio;*
s vult simpliciter verti; *p* vero per accid.;
m vult transponi; *k* per impossibile duci.*

A single illustration will suffice to show the application of these ingenious mnemonic symbols. Let us take the following example in *Dimaris*, a mood in the fourth figure:—

Dim..............Some mysteries are *believed by Christians;*
a..............*All that is believed by Christians* is credible;
ris..............Some credible things are mysterious.

Here the *m* indicates transposition of the premisses; *s*, that the conclusion is to be simply converted. Then, as the initial letter D denotes, the syllogism will be reduced to *Darii*, one of the four perfect moods. Performing, therefore, these operations as directed, we have the syllogism thus:—

Da..............*All that is believed by Christians* is credible;
ri..............Some mysteries are *believed by Christians;*
i..............Some mysteries are credible.

The following table may be useful as showing in a condensed form the method of reducing each of the moods in the manner that the letters indicate.—Note. The mood to be reduced is called the *reducend;* that to which it is reduced, the *reduct.*

REDUCENDS.	REDUCTS.	METHOD OF REDUCTION.
Figure II.	Figure I.	
Cesare,	Celarent,	Convert major premiss simply.
Camestres,	Celarent,	Transpose premisses; convert the minor and conclusion simply.
Festino,	Ferio,	Convert the major premiss simply.
Baroko, or	Barbara,	*Reduce indirectly*, substituting contradictory of conclusion for minor premiss.
Fakoro,	Ferio,	Convert major premiss by negation.
Figure III.	Figure I.	
Darapti,	Darii,	Convert major premiss *per accidens.*
Disamis,	Darii,	Transpose premisses; convert the major and conclusion simply.
Datisi,	Darii,	Convert minor premiss simply.
Felapton,	Ferio,	Convert minor premiss *per accidens.*
Ferison,	Ferio,	Convert minor premiss simply.
Bokardo, or	Barbara,	*Reduce indirectly*, substituting contradictory of conclusion for major premiss.
Dokamo,	Darii,	Convert major premiss by negation, and transpose premisses.
Figure IV.	Figure I.	
Bramantip,	Barbara,	Transpose premisses; convert conclusion *per accidens.*
Camenes,	Celarent,	Transpose premisses; convert conclusion simply.
Dimaris,	Darii,	Transpose premisses; convert conclusion simply.
Fesapo,	Ferio,	Convert the major premiss simply; the minor *per accidens.*
Fresison,	Ferio,	Convert the major and minor premisses simply.

Except in the cases of Baroko and Bokardo, the initial letters do not indicate the moods in the first figure to which the imperfect moods are reducible by the *indirect method.* This method is, indeed, seldom adopted, except for the two moods in question, and may be dispensed with in these cases also, as shown in the preceding table. To complete our view of the

* B indicates *Barbara; Celarent* reduces C;
D returns to *Darii;* F to *Ferio;*
s means simple conversion; *p* conversion *per accidens;*
m means transposition; *k* indirect reduction.

doctrine of Reduction, we may, however, add a list of the *reducts* corresponding to *all* the imperfect moods by

THE INDIRECT METHOD.

Reducends.	Reducts.
Baroko, Felapton, Bokardo	*Barbara.*
Festino, Darapti, Disamis, Bramantip, Dimaris	*Celarent.*
Camestres, Ferison, Camenes	*Darii.*
Cesare, Datisi	*Ferio.*
Fesapo	*Barbara or Celarent.*
Fresison	*Darii or Celarent.*

PHRENOLOGY.

CHAPTER XIII.

ORDER II.—INTELLECTUAL FACULTIES.

The essential nature of these faculties is *to know.* The existence of external objects, with their physical qualities and relations, are by these acquired. They are subdivided into external senses, perceptive faculties, and reflecting faculties.

GENUS I. EXTERNAL SENSES.—GENERALITIES.

Since the time of Locke, the greater number of philosophical systems rest upon the axiom of Aristotle. According to this hypothesis, the perfection of the mental functions depends on the perfection of the external senses. This, however, neither holds good in the case of animals nor men. Many animals have the senses more active and more perfect than men. No animal, however, can at all approach man in intellect. Many idiots have the external senses healthy and energetic, but this is no remedy against the deficiency of understanding. A most conclusive proof of the innate dispositions of the mind is found in the case of Laura Bridgman, who, deprived of sight, hearing, speech, and smell, yet displays great intellectual power and strong affective feeling. The external senses are merely the instruments by means of which the internal faculties, acted upon by external impressions, manifest their activity. They do not acquire any knowledge of external objects, or of their qualities and relations. The eyes do not judge of colour. The ears do not appreciate or produce melody, neither do they invent any verbal language. The smell does not possess local memory, nor does the touch give rise to the instinctive labours of animals, or the mechanical arts of man.* It remains to specify some functions of the senses.

Since 1815 (continues Spurzheim), in my lectures and publications, I have maintained that the nerves of motion differ from those of feeling, and I have adduced anatomical, physiological, and pathological proofs in support of my position.

Feeling.—The sense of feeling is the most extensive of all the senses, being continued not only over the whole external surface of the body, but also over the intestinal canal. It produces the most general perceptions of pain and pleasure, of temperature, and of dryness and moisture. All its other functions are mediate, that is, internal faculties perceive the numerous impressions it propagates.

Taste.—The sphere of activity of taste is confined to the perception of savours; it is particularly useful to nutrition.

Smell.—The sense of smell procures the sensations of odour. All its other functions are mediate. By its means, the world begins to act upon man and animals from a distance, odorous particles being detached from external bodies, and affecting the olfactory nerves. This sense informs animals of the existence of their food, and of the approach of friends and enemies.

Hearing.—The immediate function of the sense of hearing is the perception of sound; but it assists many of the internal, more especially of the affective powers.

Sight.—The sense of sight perceives light and its different degrees of intensity; it also informs man and animals of remote objects by means of an intermedium. Sight and hearing appear commonly later after birth than the other senses. Some animals, however, come into the world with perfect ears and eyes. Others are said to learn to hear and to see; that is to say, they come into the world with imperfect organs of sight and hearing.

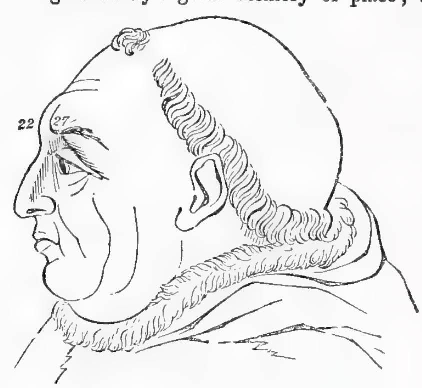
* See Spurzheim on the External Senses.

GENUS II. PERCEPTIVE FACULTIES.

These faculties are destined to make man and animals acquainted with existences, with the physical qualities of external objects, and with their various relations.

22. Individuality.—The organ of Individuality is situated behind the root of the nose, between the eyebrows, where it is large; it is found in connection with that beautiful form of nose denominated Grecian.

After Dr. Gall had discovered an external sign of the talent of learning by heart,* he was not long in perceiving that it by no means indicated every species of memory. He observed that among his school-fellows some excelled in verbal memory, and remembered even words which they did not understand, while others were deficient in this qualification, but recollected, with uncommon facility, facts and events; that some were distinguished by a great memory of place; some were



POPE MARTIN V.

22. Individuality. 27. Locality.

able to repeat, without mistake, a piece of music which they had heard only once or twice, while others excelled in recollecting numbers and dates; but no individual possessed *all* these talents combined in himself. Subsequently to these observations, he learned that philosophers before him had arrived at similar conclusions, and had distinguished three varieties of memory—*memory of things*, *verbal memory*, and *memory of places*. In society, he observed persons who, though not always profound, were learned, had a superficial knowledge of all the arts and sciences, and knew enough to be capable of speaking upon them with facility, and he found in them the middle of the lower part of the forehead very much developed. At first he regarded this as the organ of the "memory of things," but, on further reflection, he perceived that the name "memory of things" does not include the whole sphere of activity of the organ now under consideration. He observed that persons who had this part of the brain large, possessed not only a great memory of facts, but were distinguished by prompt conception in general, and an express facility of apprehension, a strong desire for information and instruction, a disposition to study all branches of knowledge, and to teach these to others; and also, that if not restrained by the higher faculties, such persons were naturally prone to adopt the opinions of others, to embrace new doctrines, and to modify their own minds according to the manners, customs, and circumstances with which they were surrounded. He therefore rejected the name "memory of things," and used the appellation somewhat analogous to the "sense of perfecting education." Dr. Spurzheim distinguishes this faculty as that "which recognises the existence of individual beings, whose activity and presence are denoted by substances in language. I acknowledge," says he, "that no objects are inseparable from their qualities, and that these constitute objects, but I think it possible to conceive existence or entity without

* Gall's Works, Vol. IV., p. 233.

knowing its qualities—as God—the mind." These views of Dr. Spurzheim have fixed the name of the organ.

Individuality is exceedingly exact in particularizing facts and data, even those which are considered by some as trifling and unimportant. That mighty master of the human mind, Shakspeare, has illustrated this faculty in the character of Dame Quickly. Falstaff having promised her marriage, merely to obtain his ends at the time, wishes to evade the fulfilment of his promise; but the dame calls to his remembrance all the different particulars at the time of the promise, and this so exactly, as completely to put the knight to silence, though himself exceedingly fertile in the invention of a lie. "Thou didst swear to me," says she, "on a parcel gilt goblet, sitting in my dolphin chamber, at the round table, by a sea-coal fire, on Wednesday, in Whitsun week, when the prince broke thy head for likening his father to a singing man at Windsor. Thou didst swear to me then, as I was washing thy wound, to marry me, and make me thy lady, thy wife. Canst thou deny it? Did not gudewife Keech, the butcher's wife, come in then, and call me Gossip Quickly; coming in to borrow a mess of vinegar, telling us she had a good dish of prawns, whereby thou didst desire to eat some, whereby I told thee they were ill for a green wound; and didst thou not, when she was gone down stairs, desire me to be no more so familiar with such poor people, saying, that ere long they would call me madam, and didst thou not kiss me, and bid me fetch thee thirty shillings? I put thee now to thy book oath. Deny it if thou canst." In this short speech of honest Dame Quickly, there are no less than twenty-six particulars individualized.

In philosophers this organ is highly useful. Investigation, in the most minute sense of the word, may be said to characterize it. Though it is impossible not to feel regret at the insane folly which characterized most of the alchymists in search of the philosopher's stone, yet are we much indebted to many of them for several very valuable additions to chemical and philosophical knowledge. The minute operations which they pursued, could only have been the result of a large Individuality.

Among philosophical writers, we may perceive different varieties of this faculty exemplified. Le Sage, De Foe, and Sir Walter Scott have, in their portraits, this organ fully developed. In a healthy state, it seems to bring all the faculties into full play. In a state of too great activity, it is productive of desultoriness and restlessness of observation, a perpetual prying into matters which does not concern them, and in consequence leads to a degree of exaggeration, very much after the manner of the Cretans, who, as the Apostle observes, are always liars.

Among the Hindoos this faculty is large, and Conscientiousness very small, and they have an utter disregard for truth. Sir William Jones has been heard to say, that in the bazaars of Calcutta he could purchase affidavits cheaper than asparagus. In the character of the Thugs, given in the 530th page of the 1st vol. Phrenological Journal, Mr. Smith observes:—"The extraordinary ability displayed by the Thugs in ascertaining the characters, trade, name, residence, and intentions of their victims; the adroitness with which they wound themselves into their confidence; and the strong recollection of facts which have occurred many years before, all display, in a wonderful manner, the tact and ability of their leaders, and the scientific and lasting principles on which the association is founded."

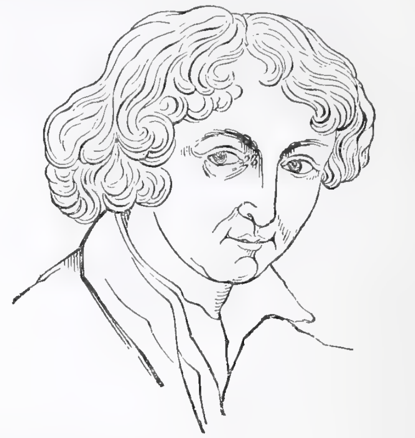
23. Form.—The organ of Form is situated in the internal angle of the orbit. If large, it pushes the eyeball outwards and downwards, towards the internal angle, and thus separates the eyes from the root of the nose, and from each other.

Dr. Gall was struck with the curious fact,* that certain persons and animals recognise, with the greatest ease, individuals whom they have once seen, though years may elapse before they meet them again.

Being desired to examine the head of a young girl who had an extreme facility in distinguishing and recollecting persons, he found her eyes pushed laterally outward, and a certain squinting look; after innumerable additional observations, he spoke of it as the organ of the "knowledge of persons."

* Works, Vol. V., p. 1.

Dr. Spurzheim's designation appears to us to be the more appropriate and correct, namely, Configuration. "To me there seems to exist an essential and fundamental power," says Dr. Spurzheim, "taking cognizance of configuration generally, and one of whose peculiar applications or offices is recollection of persons, for persons are only known by their forms. I separate the faculty which approaches Configuration from that of Individuality, since we may admit the existence of being, without taking the figure into consideration. Individuality may be excited by



every one of the external senses, by smell and hearing as well as by feeling and sight, while the two latter senses alone assist the organ of Configuration. It is this power which disposes us to give a figure to every being and conception of our minds, that of a venerable man to God—to death a skeleton, and so on. This organ varies in size in whole nations. Many of the Chinese have it much developed. It is commonly large in the French, whose skill in producing certain elegant articles of industry is well known; combined with Constructiveness, it invents the patterns of dressmakers and milliners. It leads poets to describe portraits and configurations, and induces those who make collections of pictures and engravings to prefer portraits, if they have it in a high degree." In a work called "Arts and Artists," Vol. I. p. 118, it is related that "a man of the name of Huber had acquired such a facility in *forming Voltaire's* countenance, that he could not only cut out most striking likenesses of him out of paper with scissors held behind his back, but could mould a little bust of him in half a minute out of a bit of bread; and, at last, used to make his dog manufacture most excellent profiles, by making him bite off the edge of a biscuit, which he held to him in three or four different positions."

Many of the lower animals are illustrations of this faculty; lambs never err in singling out their own dams, although to an ordinary observer there is nothing to distinguish them from others. Bees know those of their own hive from strangers, although there appears to us no difference in their configuration. Those who excel in portrait painting have this faculty large, and any individual who might employ a painter, and expect a striking fidelity to the original, would assuredly be disappointed, if the artist did not possess a large Configuration. In the portrait of that most amiable man and most admirable sculptor, Flaxman, Configuration, Veneration, and Benevolence are largely developed; and, accordingly, he selected almost all religious subjects for his chisel. The head of Chantrey, who was during his life considered at the head of his profession, was also very strikingly developed in Configuration. When this faculty is in too energetic a state, it is constantly engaged in imitating various figures, and in throwing them into all manner of attitudes; it is, therefore, one of the elements of caricaturing. In Dr. Gall this organ was very defective, for often, in rising up from table, he could not remember the person that sat next to him, so as to be able to recognise him again in society; and, in consequence, he was not unfrequently exposed to many painful embarrassments and awkward mistakes.

Immediately above the organ of Configuration is situated—

24. SIZE.—"The faculty of distinguishing form differs from the faculty of size," says Mr. Combe. "The size may be the same, and the form different. One of these kinds of knowledge may exist without the other, and there is no proportion between them. Dr. Spurzheim, therefore, inferred by reasoning, that there would be a faculty, the function of which is to perceive size; and observation has proved the soundness of this conclusion, for the situation assigned by him to the organ has been found to be correct. A member of the Phrenological Society called on Dr. Spurzheim at Paris, and the doctor observed to him that he had the organ of Size largely developed. This proved to be a correct indication of the talent in his case, for he possesses the power of discriminating size with great nicety. He is able to draw a circle without the aid of any instrument, and to point out the centre of it with mathematical accuracy. Being in the army, he found himself able to make his company fall from column into line with great exactness, estimating correctly by the eye the space to be occupied by the men, which many other officers could never learn to do."* Among professors of the useful arts, we frequently give preference to particular individuals who have such exact ideas of proportion, that if they are but informed of the size of a building, they will have every article of furniture corresponding. Thus, a cabinet-maker who has this faculty large, will never take an order until he has been either accurately informed of the size of the apartment, or otherwise seen the room where it is to be placed. A joiner will fit up a shop with the strictest attention to every part receiving its just proportion, an architect will bring into use and beauty every inch of ground upon which he intends to build; and a geometrician and mathematician will measure, with the nicest accuracy, the heavenly bodies or terrestrial objects. Of these organs of Configuration and Size, we have some striking illustrations in the erection of the temple of Solomon.

Adjoining Size, at the commencement of the eyebrow—

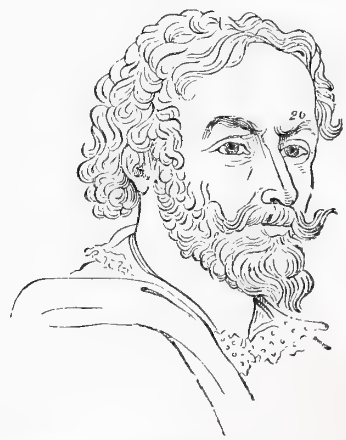
25. WEIGHT is situated.—This faculty is as yet involved in some degree of conjecture. Dr. Spurzheim dismisses it in half a dozen lines; but Mr. Combe notices some interesting particulars in connection with it. The faculty being in the vicinity of Form, Size, and Individuality, would lead us to conclude that it is a necessary adjunct to the whole; and if this be admitted, then such a faculty must be necessary to the formation of a good mechanic. In men whose minds dispose them to mechanical pursuits, we have often observed that the parts where Size and Weight develop themselves give a heavy lowering brow, so that a physiognomist would, in many instances, pronounce them as a crabbed and ill-natured set. We have known persons of whom we have formed a similar opinion, but who have turned out upon acquaintance to be men of the best hearts, and of the utmost good-nature. A gentleman of our acquaintance in Newcastle, and an engineer in the same town, present a most remarkable configuration of this sort. They are both largely developed in Weight. The reason, therefore, why we see so many engineers with heavy brows, is owing to the large development of the organs of Size and Weight. In man as well as animals, a knowledge of gravity or weight is indispensable for the preservation of the equilibrium. This power is in some more distinctly and fully developed than in others. Two persons unexpectedly meeting, one perhaps hastily coming from an avenue or turning a corner, the other as hastily passing, are differently affected by the violence of the collision. One stands like a ton of iron, the other staggers beneath the force of the resistance, and would assuredly fall were it not for the support which the opposing power lends. We have observed, and considered it remarkable, that in those in whom this faculty is large, in coming in collision with those in whom it is deficient, they generally catch them in their arms to prevent their falling. Dr. Epps knew a founder, who, endowed with all the perceptive faculties, so large as to amount to a positive deformity, was perpetually complaining of his men, because, when working in iron, they used too much or too little force. Had the founder known phrenology, he would not have expected from men who had not so full a development of the organ as himself, the same degree of tact. In animals, the power of weight or gravity may be said to manifest itself strikingly. If a cat be thrown from ever so great a height, it will constantly alight on its feet, thus showing that it estimates the force of the air, and provides, by the disposition of its body, for the spot on which it expects to alight.

A bird estimates the force of the air, and expands or diminishes its tail and wings as it rises into or descends from the atmosphere. A fish estimates the weight of water, and exerts its fins and tail accordingly to overcome the resistance. The facility of recovering the balance by a sudden jerk of the hand, is no doubt familiar to all. All these instances prove, that whether the organ be yet fully established or not, there must be a faculty which cognizes weight. But the part now indicated seems to be the real spot where this function develops its powers.

Sir Isaac Newton discovered the power of gravity, and one might, therefore, conclude that in him this organ should have been large: and in an essay read before the Phrenological Society by Mr. Simpson, and published in Vol. II. p. 410 of the Phrenological Journal, Mr. Simpson says:—"We saw both the statue and bust of Sir Isaac Newton and Rubiliac. The bust was a likeness taken in the prime of his years, and in it the knowing organs are still more prominent than in the statue. Weight is very prominent. The same organ is very largely developed in the bust of the lamented Dr. Clarke the traveller, and, as might have been expected, Locality quite extraordinarily developed." When this organ is in a state of great excitement, it may probably manifest itself in some of those hazardous feats exhibited by equestrians and rope-dancers.

26. COLOURING.—This organ is immediately adjoining Weight, and in the centre of the eyebrow. The functions of the organ consist in the distinction of colour in all its variety of tints and shades.

Though the eye is the organ by which we are presumed alone to be able to distinguish colour accurately, it is well known that there have been, nay, now are in existence, persons who have been unable to distinguish colour; and that, too, though in other respects the organ of sight has been singularly acute. This, therefore, proves that the organ of Colouring is an independent faculty; and this accounts for the fact that many artists, who are singularly correct in the construction of their pictures, are greatly deficient in colouring. Some artists have been known to produce the most exquisite sketches in pencil, who, when they have taken a brush in hand to colour, have produced the vilest daubs. Dr. Spurzheim mentions a family, the whole of the individuals composing which could only distinguish black and white, which, technically speaking, are no colours at all; and Dr. Epps mentions a tailor with whom he is acquainted, who is so deficient in the organ of Colour, that he frequently puts the cloth which is for lining the inside of the collar outside: his wife is obliged to exercise a vigilant superintendence over him to prevent this. Mr. Combe mentions a case of Mr. Milne in Edinburgh, which is equally



RUBENS.

* Combe's Phrenology, p. 283.

authentic:—"Mr. Milne's grandfather, on the mother's side, had a deficiency in the power of perceiving colours, but could distinguish forms and distance easily. On one occasion this gentleman was desirous that his wife should purchase a beautiful green dress. She brought several patterns to him, but could never find one that came up to his views of the colour in question. One day he observed a lady passing on the street, and pointed out her dress to his wife, as the colour that he wished her to get; when she expressed her astonishment, and assured him that the colour was a mixed brown, which he had all along mistaken for a green. It was not known till then that he was deficient in the power of perceiving colours." All these instances concur in establishing the fact, that the organ of *colour* is an independent power. This organ is indispensable in a dyer, painter, or enameller; success in either of these branches would be hopeless without it.

In a memoir of the late Mr. Troughton, the well-known astronomical instrument maker, which appears in the annual report of the Astronomical Society, 1835, there is the following statement:—"The only astronomical instrument which is not greatly indebted to Mr. Troughton is the telescope; and he was deterred from any attempt in this branch of his art, by a singular physical defect which existed in many of his family. He could not distinguish colours, and had little idea of them, except, generally, as they conveyed the idea of greater or less light. The ripe cherry and its leaf were to him of one hue, only to be distinguished by their form; and he was in the habit of relating some curious mistakes committed by himself, and others of his relations, in confounding green and red. With this defect in his vision, he never attempted any experiments in which colour was concerned, and it is difficult to see how he could have done so with success."*

27. Locality.—This organ is situated immediately above Weight, and adjoining Eventuality. In the discovery of this organ, Dr. Gall relates, that being much attached to the study of natural history, he frequently went into the woods to snare small animals, and to catch birds, and to explore their nests; and though he was expert in this, yet he experienced great difficulty in returning to the same spot, even though he might have marked the tree, and placed boughs of trees near to serve him as a guide. He had a schoolfellow named Schiedler, who, without any apparent effort, went directly to the tree where the nest was, or to the spot where the snare was set; and though they might set many snares in places where they never had been before, Schiedler never failed to find them out. As this boy was possessed of but very ordinary talents in other respects, Dr. Gall was much struck with his facility in remembering places. "How is it," said he one day to Schiedler, "that you contrive to find your way so easily through intricate places, through which you have only once been?" "How is it," replied his companion with the same feeling of surprise, "that you contrive *not* to find yours?" Hoping to come to a knowledge of this property at a future day, Dr. Gall moulded his head, and closely observed the persons of others who had the same facility of remembrance. He was informed by the celebrated landscape painter, Schoenberger, that in his travels he was accustomed to make only a general sketch of the objects that interested him, and when he wished to make a picture at any time afterwards, bushes, trees, and even stones, rose spontaneously to his mind, and upon comparing them with the original scenes were always found correct.

Dr. Gall next became acquainted with M. Meyer, who wrote a romance called "Diana Sore," and who found no pleasure so great as wandering from place to place. Having also moulded his head, he placed the three side by side, and though they were different in every other respect, they all presented the same appearance at the spot now indicated as the seat of the organ. He also met one day with a woman, who had such large protuberances in this spot, that the forehead was quite deformed by it; and on discoursing with her, he found she had the greatest desire to travel, that she never remained long in the same country or in the same house, her greatest delight being to visit strange places. From all these observations, Dr. Gall concluded that the faculty of remembering places depended upon a primitive organ; and experience has since demonstrated this to be true. That this is absolutely the case may be demonstrated from the fact, that even where sight is deficient, and in some cases wholly extinct; if Locality be large, the individual finds no difficulty in finding his way with the greatest apparent ease. The celebrated blind traveller, Holman, is an instance of this faculty, and with it, I should think, associated a pretty large share of Benevolence. "In all my travels," says he, "I cannot recall a single instance in which any person attempted to take advantage of the confidence I reposed in them, either in the receipt, exchange, or payment of moneys. In making bargains, or estimating the quality of articles by their prices, whenever I depended on my own judgment, I do not remember that I ever had any reason to be dissatisfied, nor do I think that in such matters I was more imposed upon than I should have been, had I possessed my sight. Notwithstanding I have travelled so much in foreign countries, and had so extensive an intercourse with strangers, I think I can safely say that I have not been more deceived, or suffered greater losses in money transactions, than any of my countrymen. Thank God I have not found sufficient cause to arm myself with suspicion: for although there are despicable characters in all countries, who would not hesitate to take advantage of others, I am happy to think that human nature is not so bad as she is portrayed." There is considerable benevolence in this description of mankind; but the feeling of sympathy which the most callous sometimes may exemplify when viewing the deprivations of others, may not have been wholly without its influence in this treatment of the blind traveller. My principal object was, however, to bring forward Holman as an instance of the faculty of Locality. Again, the poet Rogers is an exemplification of this faculty, and in his portrait the organ is large; thus he observes:—"Would he who sat in a corner of his library, poring over books and maps, learn more, or so much in the time, as he who, with his eyes and his heart open, is receiving impressions all the day-long from the objects themselves? Assuredly not. Knowledge makes knowledge, as money makes money, nor never, perhaps, so fast as on a journey. How accurately do the *forms* arrange themselves in our memory—*towns, rivers, mountains;* and in what *living colours* do we recall the *dresses, manners,* and customs of the people!"* All this is true in the case of an individual who, like Rogers, may have large knowing organs and a good Locality; but it would be but little attractive to him in whom Inhabitiveness was large, and the organs of Form, Size, Colour, and Locality deficient. In short, it will be found an invariable truth, that as the organs which develop themselves on the head predominate, so will the attachments of the individual tend, and nothing is more true in this respect than in Locality.

"The influence of local attachments," says a writer in the Retrospective Review (ix. 237), "is closely interwoven with the most exalted qualities of the mind. The solitary vale of an unknown and nameless river, a sequestered rural parish, or the territory of an extinguished and forgotten lordship, may furnish recollections of the deepest interest. Homer is no less deserving of being ranked as the first of topographers, than as the first of poets; and Sir Walter Scott is an example of the union of the poetical and topographical faculties." Now, in both Homer and Sir Walter Scott, the faculties of Ideality and Locality are both large. In Sir Walter Scott, this must be in the recollection of all who have read his writings, or seen his person or bust; and in Homer too, in his bust these faculties are large.

It is no argument against this to say that we cannot vouch for the fidelity of the bust of Homer to the original. Ideality and Locality are large, and if the bust be not a correct likeness, then the original modeller must have been a phrenologist, and one, too, who wished to show its power in the modelling of the head of so eminent a personage; but as we have no proof of this, we can, therefore, only argue that the likeness affords a strong probability of correctness from the very circumstances of the full developments of such organs. In the mask of Napoleon, this organ is in accordance with the faculties of Comparison, Causality, and Benevolence, *i.e.*, large. He was

* Penny Magazine, May 14, 1836.

* Rogers' Italy, p. 172, 173.

a native of Corsica, and after a protracted endeavour to subjugate Europe, when at length he was confined to the rock of St. Helena, was represented to have said to Mr. O'Meara, his surgeon, "that if led blindfolded to Corsica, he would embrace with rapture a soil, whose very smell would enable him to recognise it." Dr. Spurzheim describes the functions of this faculty as Locality in general. As soon as we have conceived the existence of an object and its qualities, it must necessarily occupy a place, and this is the faculty that conceives the places occupied by the objects that surround us.* Sir George Mackenzie is of opinion that the primitive faculty is that of perceiving relative position, and if this be admitted, then it will be essential in description, and no person will be able to delineate well without a due share of this faculty in unison with Size and Form. There are times when the stranger in a foreign land recurs, with a melancholy pleasure, to the localities of his own native land. A fine instance of this is given by Mr. Riland in his Memoirs of a West India Planter. "Ah, Sir!" (said poor old Cesar, a slave) "every one loves his native land, the place where his fathers lived, the trees, flowers, and animals; and I think with pleasure even upon the dreadful snakes, because they belong to my country. The sky is there not constantly covered with clouds, and always dripping with rain, though we had our rainy seasons; but then they were more regular, and we knew when to expect them. The sun does not there bathe his beams in mists and fogs, but pours its kindly influence on all things, and you can't imagine how fast it makes the plants grow; the wide-spread trees give cool shadows, superior (but you will smile at me) to the finest palaces I ever saw in Europe; all was delightful, except the curse of the slave trade." The effects of this organ vary as the other faculties predominate; where Weight, Number, and Order is large, the individual will excel in astronomy; where Size and Form are large, and if combined with Colour, the possessor will excel in landscape painting. Where the organ is in too active a state, there will be restless anxiety for change of place. A feeling like this exists in migratory birds. Mr. Robert Sweet, of Chelsea, London, keeps a great many of the migrating birds, and in a little essay, called British Warblers, he gives the following account:—"These birds when in confinement are very restless at the seasons of their usual emigration from one country to another: in autumn; about twice during the winter; and again at their return in the spring. From their agitation at various times in winter, it may be concluded that they visit more than one country after their departure from this. It is very curious to see them when in this state. Their restlessness seems to come at once, and generally in the evening. When they are sitting, seemingly quite composed, they start up suddenly and flutter their wings: sometimes flying direct to the top of the cage or aviary, at other times running backward or forward on their perches, continually flapping their wings, and looking upward all the time. Nor will they notice anything that is going forward, as long as they continue in this state, which lasts for an hour or two at each time. By their wishing to fly upward, it may be supposed that, when they first direct their flight, they mount upwards to a great height, so that they can direct their course the better, by seeing the way clear all round them. Their agitation generally lasts about a fortnight, sometimes more and sometimes less: in the spring it seems strongest on them. At that season they will sometimes flutter about the whole of the night, and sleep a great part of the day."

The organ of Locality is also strong in several of the inferior animals; in particular, in horses, dogs, and cats; and we should imagine (though I have never had an opportunity of judging by observation) it must be large in the carrier pigeon. Every person who has travelled with a road horse, must have experienced the disposition of the animal to stop at a particular inn. Of the dog, many anecdotes are related where the functions of this organ are strikingly conspicuous; and in the cat it is also well known, and is easily to be distinguished when the head has been anatomised. Swallows not only return to the same country, but, as is frequently observed, to the same place, to the roof of the same house, and to the spot in that house over a particular window. In the portraits of Columbus and Cook among travellers, and of Kepler, Galileo, Newton, Tycho Brahe among astronomers, this faculty is very large. In Sir Walter Scott, and the portrait of the celebrated George Bidder, the faculty is also large, and all eminent calculators have a peculiar Locality, by which, with the greatest facility, they string together the most astounding numbers.

* Spurzheim's Phrenology, p. 280.

28. Number, or Calculation.—The organ of Number is placed at the external angle of the orbit; if it be large, this part projects and appears full. It embraces whatever concerns number: hence, algebra, arithmetic, and logarithms belong to it.

A scholar of St. Poelton, near Vienna, being much spoken of on account of his arithmetical talent, Dr. Gall sent for him to Vienna. He was the son of a blacksmith, and had received no other education than is bestowed upon young persons in a similar walk of life. Dr. Gall observed in this boy a remarkable prominence in the external angle of the eye. "I presented him," says Dr. Gall,* "to my audience: at this period he was nine years of age. When they gave him three numbers, each expressed by ten or twelve figures, asking him to add them, then to subtract them two by two, to multiply, and then divide them by numbers containing three figures; he gave one look at the numbers, then raised his nose and eyes in the air, and announced the result of his mental calculation, before my auditors had time to make the same calculation with their pens in their hands. He had created his method himself."

An advocate of Vienna having stated his regret that a child of his spent all his time, even to the exclusion of childish sports, in arithmetical calculations, Dr. Gall examined him, and found a similar prominence in the same situation. He next observed the head of Counsellor Mantelli, who was constantly occupying himself in the invention and solving of mathematical and arithmetical questions, and again the same prominence presented itself. Pondering on this, he visited several schools, and always found that those who excelled in arithmetical talent had this peculiar configuration. In Baron Vega, author of Tables of Logarithms, and at that time professor of mathematics, he also discovered a similar configuration; and he excelled in this particular department of science, although in everything else the doctor considered his talents as nothing above mediocrity. From all this evidence, Dr. Gall concluded that this was a primitive faculty. Arithmetical talent has often been exemplified in children in this country, and has called forth much discussion

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among metaphysicians, as to whether the faculty is intuitive. Some teachers are of opinion, that boys of moderate talent may, by diligent practice, be brought to equal, if not rival the feats of the celebrated Zerah Colbourn, the American calculator. Mr. Hill, in his "Plans for the Education and Liberal Instruction of Boys in large Numbers," says:—"At one of our public exhibitions, a class of ten or twelve boys stood prepared to extract the cube roots (disregarding fractions) of any numbers, whether exact cubes or surds, which did not exceed two thousand millions. Many gentlemen present were furnished with

* Works, Vol. V., p. 81.

tables of cubes and their roots: several questions were proposed, and answered with a rapidity which astonished the audience. This class had received very frequent practice, with the view of trying whether boys of tolerably good talents could not be educated to rival, or even to exceed the feats of this kind performed by the American youth, Zerah Colbourn." There is no doubt but boys who have a good development of Number may, by training, be brought to exhibit the most astonishing arithmetical talent. But if Mr. Hill, or any other educator, were to take 10 or 12 boys in whom this particular configuration was not to be found, all the drilling to which he might subject them would never enable them to exhibit powers above mediocrity.

George Bidder, the celebrated youth that caused so much astonishment in the metropolis some years since, has this faculty very largely developed, as well as the faculty of Locality. A gentleman desirous of putting his extraordinary powers to the test, asked him the following question:—How many pinches of snuff have I taken within the last twenty years, supposing I have taken a pinch every five minutes; and what is the quantity I have taken, supposing every pinch to weigh a grain. In about the same time as the gentleman had taken to propose the question, a correct answer was given, which consisted of not a few figures. For the information of those whose snuff-taking propensities may not render them sufficiently curious to make the calculation, I may inform them that the gentleman took 3 cwt. 1 qr. 1 lb. 3 oz. in about 2,103,840 pinches. That Number is a primitive faculty, and does not require the aid of the organ of sight, may be evident from the case of Professor Sanderson, who occupied, in so distinguished a manner, the chair of mathematics in the University of Cambridge, and he was quite blind.

The faculty of Number must, however, exercise many of the reasoning powers, since it has been found wonderfully to come to the most accurate conclusions: in no case was this more evident than in the individual now before us, Sanderson. Being in a large company, he remarked of a lady that had just left the room, that she had very white teeth. The company were extremely anxious to learn how he had discovered this, for it happened to be quite true. "I have no reason to believe," said the Professor, "that the lady is a fool, and I can think of no other motive for her laughing incessantly for a whole hour together." It is evident from this, that the reasoning powers of the mathematician must have been large: hence, in addition to Number, there must have been good comparison, Causality.

Locke recommends that all children should be taught mathematics, not so much to make them mathematicians, as to make them reasonable creatures. When this faculty is excessively active, it leads to absence of mind upon every other subject than the all-absorbing one of Number. Fits of abstraction ensue from this, which at times are not a little ludicrous. This is well exemplified in an incident which happened to a well-known gentleman at Magdalen College, Cambridge. He had taken his watch from his pocket, to mark the time he intended to boil an egg for his breakfast, when a friend entering his room, found him absorbed in some abstruse mental calculation with the egg in his hand, and the watch supplying its place in a saucepan of boiling water. Where this faculty is deficient, there is an inaptitude for calculation, and great difficulty in discriminating the power of numbers.

In Mr. Combe's Notes on America, Vol. III., p. 204, there is an amusing instance of this, in which the great phrenologist himself is at fault.

"A gentleman," says he, "who kindly undertook the management of the tickets for my lectures at Lowell, wrapped up the sum received from each bookseller in a separate paper, and made the person who paid it mark on the parcel the amount it contained. When he paid the bill for advertising, &c., he took the money wanted out of one of the parcels, and put the receipts for the payments into it, and brought the whole sums collected to me in this form. Not understanding why he had done this, I placed the contents of the whole parcels together, and asked him how much he had received, and how much he had paid? He could not tell! I then observed that his organ of Number was deficient, and he told me that he had adopted this method to avoid confusion. My own organ of Number being equally small, we tried, both by the pen and by counting the money, to discover the amount, but neither of us could succeed! We finally parted much to our own amusement, without either of us having been able to find out the aggregate sum either received or paid, and certainly it was not the magnitude of the amount that caused our difficulties. A deficiency of this kind, when it occurs in the organ of Number, occasions only amusement. But I never experience its effects without sincerely sympathizing with those individuals, who are as defective in the organs of Conscientiousness or Causality as I am in Number. They stand as much in need of external guides to virtue and wisdom, as a man in my condition does of a 'ready reckoner.'"

The Esquimaux are particularly deficient in this organ, and in them the configuration is in strict accordance. Captains Parry and Lyon remark, that the eyes of the Esquimaux are turned up at the exterior angle; they have the peculiarity of not being horizontal, as with us, but coming much lower at the end next the nose than at the other. This configuration is in all alike.

In the portrait of Jedediah Buxton, this organ is very prominent. He was unable to read or write, but his knowledge of Number and his facility of working intricate arithmetical questions was marvellous; but our space is exhausted, and we cannot give further illustrations.

29. Order.—This organ lies between Colouring and Number, and Dr. Gall remarks respecting it, that from various observations which he has made, he has been enabled to elicit facts which prove that Order depends on a primitive power; but on account of the difficulty of observing the organs placed in the superciliary ridge, and the small size of this organ in particular, as pointed out by Dr. Spurzheim, he has not been able to collect a sufficient number of determinate facts to authorize him to decide on its situation. Dr. Spurzheim, however, pronounces it established. The faculty itself gives the function of peculiar regularity and method in arrangement, and when well developed, there is great neatness and cleanliness in its possessor, as well in person as in the general order and arrangement of the house. There is nothing like bustle or confusion. The motto of such a person is, "A place for everything, and everything in its place," and with him all things are done decently and in order. In the portrait of Southey the poet, this portion of the brain is prominently developed; and Order is so predominant in him in his literary pursuits, that he absolutely writes upon different subjects according to an arrangement previously made, which he is so exact in adhering to that he writes by a stop-watch. He is as orderly a mechanic in literature as can be well found; not only from day to day, from week to week, is this methodical arrangement persevered in, but absolutely from year to year.

Sir Walter Scott says, in a letter (1813) to Lord Byron, "Southey is a real poet, such as we read of in former times, with every atom of his soul and every moment of his time dedicated to literary pursuits, in which he differs from almost all those who have divided public attention with him. His whole soul is dedicated to the pursuit of literature. In this respect, as well as in many others, he is a most striking and interesting character." Surely, man of imagination was never so systematic, never so methodical as he. Rising at 8 o'clock —never before 8, though his time for retiring to bed was the sober period of half-past 10; less than 9 hours' sleep he found insufficient—he devoted the entire interspace between breakfast and dinner, that is to say, from 9 a.m. to 5 p.m. or 6 p.m., to literary toil; after dinner, he attended to his private correspondence, which was unusually large; and so pointedly regular was he, that all letters were answered on the same evening which brought them. Well might he astonish more methodical people with the amount of elaborate business which he managed, by an unvarying system of arrangement in the distribution of his time. Southey was a student on principle: he pursued the muse with a chivalric devotion that was no mere impulse of ebullient and transitory fervour, but a life-long passion, an all-pervading and ever-animating love. Hers he was, hers he

would be, in evil report and good report, in season and out of season, whether she would or whether she would not. What name in the whole catalogue of authors comes nearer the *beau ideal* of the man of letters? None was ever so perseveringly attached to his craft, none more uniformly loyal to the sovereignty of mind. He was a poet—some say of the very highest order; he was an antiquary—and had the true Oldbuck gusto for matters archæological; he was a critic—and received his hundred guineas (or thereabouts) per article for the reviews; he was a biographer—and there are able men who prefer his lives of Nelson and Wesley to all his other productions; he was an historian—and few more dilligent in research or lucid in style. In short, his industry was proverbial. Byron laughs savagely at it in his parody of the "Vision of Judgment:"—

> "He said (I only give the heads)—he said,
> He meant no harm in scribbling, 'twas his way
> Upon all topics; 'twas, besides, his bread,
> Of which he buttered both sides. 'Twould delay
> Too long the assembly (he was pleased to dread),
> And take up rather more time than a day,
> To name his works."

The sarcasm does not stifle an underlying truth most honourable to the memory of this true working man. Southey was no idler upon earth; his creed was exalted, and, as his creed was, so was his practice. His bitterest opponents must admire his conscientious industry.

When this organ is small, it leads to irregularity and slovenliness. The appearance of a slattern is but the proof of the want of order. Persons of this description have sat down with the utmost contentment in the midst of confusion, second only to Babel, and they seem to have an utter inability to rectify the abuse. The Esquimaux are instances of deficiency in this organ, and they are described on all hands as equally filthy and disgusting.

CHEMICAL MANUFACTURES.

CHAPTER II.

ON SULPHUR AND SALT, AS SOURCES WHENCE OTHER COMMODITIES ARE OBTAINED.

There is nothing so very especial in the nature of these two chemical substances as to lead to their being grouped together, and being placed distinct from others, were it not that they are so singularly valuable as sources whence other commodities may be obtained. As, however, there are some interesting chemical details connected with the original production and extraction of these valuable articles, we will collect from different sources a few facts on the matter, commencing with

SULPHUR.

There may perchance be those who would ask—"Of what use can sulphur be, except to make matches?" That it has numerous other uses, however, will be readily conceded when we state, that although an enormous quantity of the article is produced in our mining districts for home consumption, yet so great is the demand for it, that forty or fifty thousand tons are annually imported from Sicily!

Sulphur is an abundant article in the neighbourhood of volcanoes. It is widely diffused throughout the mineral kingdom, but is more abundant in some places than in others. In Iceland it is found in combination with gypsum; at Conil, near Cape Trafalgar, it occurs in a crystalline form; at Urbino in Italy, at Aragon in Spain, and at Launenstein in Hanover, large quantities are found. Beds of sulphur are very numerous in the tertiary blue clay of Sicily, a country which has supplied the greater part of Europe with sulphur for centuries, without any sensible diminution of its own stock.

The principal scene of the mining operations in Sicily is near Catolica. The sulphur appears in veins of various colours, mixed with clay and gypsum. The general appearance is that of a shining grey colour, but large pieces are found which are red and transparent, and are called by the workmen *virgin sulphur.* Large black patches also appear, consisting of a chemical combination of clay and sulphur: these patches contain beautiful crystals of sulphate of lime of various colours—yellow, violet, grey, and black.

The preparation of sulphur in Sicily for exportation, is a very simple affair. Large cauldrons are formed in an elevated mound of earth, each cauldron being about seven feet in diameter, and five feet deep. Large masses of the sulphur-stone are piled up round the edge of each cauldron, and gradually inclined so as to meet in a point at the centre; thus forming a sort of conical mound or cover over each cauldron. The spaces between the large masses are filled up with smaller lumps, and these again with dust of the same material. A quantity of straw is then spread over the mound and ignited; the straw burns, and the fire soon extends to the interior; so that the sulphur, as it melts, flows down into the cauldron. After this process has continued for about eight hours, the melted sulphur is drawn out at an aperture in the lower part of the cauldron, and received into wooden moulds, which have been previously wetted to prevent the sulphur from adhering to them. In about a quarter of an hour the sulphur becomes solid, and is then fit for exportation. In this state it is called *block sulphur*, and sometimes *massive* or *native sulphur.*

Vast quantities of sulphur are procured in our copper-smelting districts, under the name of *roll* sulphur, from the cylindrical shape in which it is cast. Most metallic ores, in the state in which they are dug from the earth, contain sulphur. The iron and copper pyrites which so greatly enrich England, are compounds of those metals and sulphur. In the smelting of copper ore, the sulphur is separated from the metal, melted in earthen pots, and cast into wooden cylindrical moulds which give it the form of rolls.

Another form in which sulphur is obtained, is that of a powder, called *flowers of sulphur.* The sulphur is melted in a vessel called an alembic. At a temperature of about 600° the sulphur rises in the form of vapour, which, being collected in the upper part of the alembic, cools down into the form of flowers of sulphur. This process is called *sublimation.* Products obtained in this way were supposed by the alchemists to resemble the flowers of plants; hence the name: but the peculiar resemblance which they saw, or fancied they saw, is not very clear.

Sulphur is an elementary body; that is, the chemist has never been able to resolve it into simpler parts. We need scarcely refer to its pale yellow colour, as it is so well known. Its weight is about twice that of an equal bulk of water. When rubbed with a piece of warm flannel, it becomes negatively electrified. One curious consequence of this property is frequently noticed by the druggist: in grinding a piece of roll sulphur in a dry Wedgwood mortar, the resulting powder adheres with considerable force to the mortar, and will not fall out when the mortar is inverted: the reason is, the sulphur becomes negatively electrified by friction, and the mortar positively electrified; and, according to a well-known law of electricity, two bodies in opposite electrical states attract each other. Hence the adhesion of the sulphur to the mortar.

Sulphur is insoluble in water and in alcohol; but hot oil and some of the alkalies will effect its solution. It is very brittle. If a roll of sulphur be grasped by a warm hand, it will often break to pieces, in consequence of its unequal expansion by heat. When exposed to heat a little above that of boiling water, it melts; at 230° it is almost as liquid as water; by raising the temperature to 600°, its colour changes from a light to a deep yellow, then to orange yellow, then a shade of red comes over it, then brown, and at its boiling point its colour is brownish-red; but the most remarkable circumstance is, that increase of temperature, so far from rendering sulphur more fluid, as is the case with most other bodies, actually thickens it, and produces a thick viscid mass: thus at 230° sulphur is quite liquid, and can be poured out of the vessel containing it; at 338° it begins to be viscid; at 428° it becomes quite thick; and from 464° to 500° the vessel containing it may be turned upside down, and the sulphur will not flow out; as it approaches the boiling point, it becomes less viscid. These remarkable facts have not been explained. When sulphur is pure, it boils away at about 600°, and leaves no residue.

If a quantity of sulphur be melted in a pipkin, and then set aside to cool, the surface will soon become solid. If we make two holes in the crust, near the edge, but opposite to each other, and incline the vessel, the melted sulphur will flow out into any other vessel placed to receive it, and air will enter at the other hole. On allowing the pipkin to cool gradually for a few hours, we shall find, on breaking open the mass, that the interior crust is composed of an immense series of small and beautiful crystals.

The above are a few points relative to sulphur and its properties generally; but we will abstract from the 'Journal of the Statistical Society,' a somewhat fuller notice of the mode of procuring it in Sicily:—

"The Sicilian sulphur is found within the limits of a geographical line which commences at the river Maccasoli in the valley of Girgenti, runs northward as far as Lercara in the valley of Palermo, tends eastward to Centorbi in the valley of Catania, and thence runs south-westerly to Terranova in the valley of Caltanizetta, where it terminates. The area of the sulphur district is about 2600 English square miles. Destitute of timber, and diversified only by fruit-trees scattered around the villages, it has few charms for the passing stranger beyond the fantastic shape of its cliffs and mountains. The man of science, however, who examines its soil, will find it replete throughout with objects of interest. The sulphur territory, the formation of which is tertiary, presents successive strata of shell, limestone, white and blue marl, intermixed with banks or beds of gypsum, and occasional patches of cretaceous matter. The sulphur is found imbedded in the lowest stratum of blue marl, which is distinguished from the upper one by the entire absence of shells. The district contains about 150 distinct mines, which are capable of yielding from 750,000 to 800,000 canters (about 50,000 to 80,000 tons) annually. Of the richest mines, those of Gallizzi, Sommatino, and Favara, the yearly production has been 100,000, 80,000, and 60,000 cantars respectively.

"The visitor to a sulphur-mine usually descends by a plane or staircase of high inclination to the first level, where he finds the half-naked miner picking sulphur from the rock with a huge and heavy tool: boys gathering the lumps together, and carrying them up to the surface; and, if water be there, the pumpmen hard at work draining the mine. A similar scene meets his eye in the lower or second level. Above-ground the sulphur is heaped up in piles, or fusing in kilns.

"Every stranger must be forcibly struck with the hardy and healthy look of the miners and burners, to which the lean and sickly aspect of the southern population forms a thorough contrast. The life of a pickman, which is sometimes said to be hard and wearisome compared with that of the peasant, is in reality easy, and suitable to Sicilian taste. His working days do not exceed 250 in the year, and his hours of labour are only six in the day. Left, therefore, with eighteen hours a day to himself, he passes three-fourths of his time in eating, drinking, sleeping, and lounging about his village. Satisfied with animal existence, the pickman seeks not intellectual pleasures at the cost of increased exertion. His wages rise and fall with the price of the mineral; from 16d. to 20d. a day for himself, and about half as much for each of his boys, are reckoned good earnings. The pumpmen are ill-paid labourers compared with the pickmen. Their daily toil, if lighter, is longer and less intermitted; and their occupation is productive of sickness, rather than conducive to health. Constantly drawing in sulphuretted hydrogen gas, which escapes from the agitated water, they suffer so severely in their eyes as often to become blind for twenty-four hours. They work for eight hours a day, and earn from 1s. to 1s. 4d. each. The burners, who extract the sulphur, by fusing the ore in kilns made of gypsum and stone, or sometimes in close vessels or furnaces, usually earn about 1s. a-day.

"The sulphur thus obtained by liquation, when hardened into cakes, is taken down to the coast by carriers and muleteers. These are mostly small farmers, who are paid by the load, according to the time of the year, and the demand for their services. Being seldom trustworthy people, these carriers are engaged by a warranter, who, for less than 1d. a cantar, becomes answerable for the safe delivery of the sulphur at the shipping place. To Palermo and Catania the sulphur is conveyed in carts; to the Southern ports it is carried down on mules and asses.

"Such is the working part of a mining establishment. The overlookers are mining captains, clerks, and a manager. The mining captain, chosen from among the pickmen for his knowledge of the mine, examines the veins and directs the operation. As the right-hand man of the manager, he is looked upon by the pickmen and others as a person whose good opinion it is worth while to cultivate. Living in a substantial and commodious house, and dressing in a neat and becoming manner on Sundays and holidays, he holds a respectable place in village society. He usually resides a few miles from the works; but in some cases he dwells at the mine, where he is required to be in constant attendance from morning till night. His wages are from 2s. to 4s. a-day; but many unlawful perquisites raise his earnings to a higher amount. After a few years' constant employment in a rich and extensive mine, he is usually able to retire with a competence sufficient for his limited wants. The clerks and watchmen, who keep account of piece-work and labourers' time, who receive the fused sulphur and weigh it out to the carriers, and who reside at the mine to take care of the works, usually earn from 1s. 8d. to 2s. 8d. a-day. The manager or head agent acts as treasurer and trustee for the owners or lessees of the mine. Aided by the mining captain and the clerks, he engages and pays the workmen, and keeps the general accounts. His salary is from 4s. to 6s. 8d. a-day. His gains are perhaps double this amount; so that he often makes his fortune in the course of a few years.

"The number of persons regularly employed in the sulphur-mines has been estimated at 4400, viz:—1300 pickmen, 2600 boys, 300 burners, and 200 clerks and others; to which, if 3600 persons occasionally employed, viz., 2600 carriers, and 1000 wharfingers, be added, the total amount will be 8000 persons more or less engaged in the extraction of ore and the exportation of sulphur. A small portion of the sulphur carried down to Girgenti serves for the use of a royal refinery, whence it is exported to France and Austria in powder and in rolls. Previous to the sulphur contract, the chief part was sent in cakes to England, France, Holland, Russia, and the United States, in the proportion of three-sixths to England, two-sixths to France, and the rest to other countries.

"In the Sicilian market, sulphur is divided into first, second, and third qualities of Licata (each of which is subdivided into best, good, and current), and into first and second quality of Girgenti, with the like subdivisions. The first and second qualities of Girgenti correspond with the second and third of Licata."

SALT.

We now transfer our attention from sulphur to salt, and show the general nature of its origin by describing salt-work operations in two or three different countries.

Three French gentlemen, many years ago, published a description of the Salzburg Salt-Mines; and as this is deemed to be very correct, we will here transcribe it:—

"The salt-mines are at a little distance from the small town of Hallein, and at the foot of the Durenberg mountain. We seated ourselves in sledges, and were conveyed to the opening which leads into the interior of the mine. Before descending into the mine we equipped ourselves in the costume of the miners, which consisted of flannel waistcoat and trowsers, and a large white cape for the shoulders. These preparations are rendered necessary by the extreme humidity of the mine, which would effectually have destroyed the common articles of clothing. We were also supplied with strong shoes, a leathern apron, and a hood. We then seated ourselves on a sort of wooden horse called a 'wurst,' which moved on four small wheels. Three of the miners attached the traces of this machine around their waists, and dragged us slowly through a long gallery, on each side of which was an aqueduct constructed of wood. One of these conveyed a supply of fresh water into the mine, and the other carried it off when it had become sufficiently impregnated with salt. In a quarter of an hour

we reached the first shaft. It is not dug in a perpendicular direction, but inclines at an angle of about 45°. It was along one of these that we were to descend to a depth of about eighty yards.

"The descent is effected in the following manner:—Two round and smooth beams are placed side by side on the lower part of the shaft, about a foot asunder. They somewhat resemble the machine used by brewers for lowering beer into cellars. They are fixed, and extend from the entrance to the bottom of the shaft. Upon these beams the person descending seats himself, placing his legs over each side, and thus slides to the bottom. A great rope is stretched on the right, about the height of the arm, in order to enable those who are descending to regulate the rapidity of their descent. One of the miners preceded each of us in the descent. My attendant placed himself between my legs, at the same time cautioning me neither to move my arms nor feet. The men then asked us if we were alarmed; to which, of course, we courageously replied in the negative. Then, abandoning ourselves to the impulse of our own weight, and each of us holding in one hand a burning torch, we glided forward so rapidly, that we were at the bottom of the 'rolle,' or beam, in half a minute. We then proceeded along another gallery, similar to the one at the entrance of the mine, and descended still deeper into the mountain by two other rolles, on which, profiting by my previous experience, I kept my seat without assistance. This mode of descending was both easy and pleasant, and I even regretted that the fourth rolle was the last.

"The mountain within whose bosom we now were, is composed of a sort of rock-salt, which is in a constant course of growth or formation. The first excavations appear to have been made at a period so remote, that tradition has not even preserved any records of the date at which the working of it was first commenced. These excavations consist of chambers six or eight feet square, into which water is conveyed by means of the aqueducts before-mentioned. The water enlarges these chambers by dissolving gradually the walls and roof. They are generally about six feet in height, and are filled as nearly as possible with water. If the chamber were half filled with water, the sides only would be submitted to the process of solution, but, by being very nearly filled, the water attracts the saline matter contained in the roof, and the operation is carried on in the most rapid, and at the same time effective manner. The miners term the roof of the chambers the 'ceil.'

"The rock-salt is of different colours, but blue, grey, and yellow are the most common. Frequently it is friable, and sometimes slaty, and peels off in transparent cakes—resembling the tracery work produced on a window by frost. There are often found, in a chamber of 613 yards in circumference, seven or eight masses of slaty rock, three or four feet in diameter, which do not contain any salt whatever. Of course, these masses resist the direct action of water, but, as all the parts round them containing salt are gradually dissolved, they are in the end detached from the roof and deposited on the floor. We saw several of these in one of the chambers we examined. The water had been drained out of this chamber three weeks before, and it was illuminated with about fifty candles. One of these masses, like a shapeless column, reached from the floor to the cieling; some, on being detached, had left cavities two or three feet deep, and several were still suspended. The miners pass carelessly under them. But that which caused me most alarm was to find myself under a ceiling 584 yards in circumference, on which the weight of the superincumbent mountain rested, and which was not even supported by the vaulted form which nature usually gives to the roofs of subterranean caverns. It was perfectly flat, and was only sustained by the adhesive forces which existed between all the various parts of this immense apartment. The firmness thus occasioned is so great, that only one instance has occurred during several centuries of a ceiling having given way.

"There are thirty-six chambers excavated in the mountain. They are partly shaped by the action of the water, and their dimensions are irregular, according as the mass composing the roof or walls is more or less charged with salt. Many chambers are excavated, one over the other, thus forming different stories, the mass which separates one chamber from another serving the same purpose as boards and lath and plaster in houses, though of course much thicker. The miners informed us, while we were examining one chamber, that above us was a chamber at that time filled with water. It may appear singular that a large body of water thus situated should not find its way into the apartment beneath, but we found the ceiling scarcely humid. The reason of this is, that before the water is introduced, the floor is covered with clay, which is beaten down so as to render the surface impervious to the water. A kind of blue clay is used for this purpose, which is worked up into a proper consistence with wooden mallets; and when it no longer contains any rough particles, it is spread over the floor. If it should leak, a little saw-dust is thrown into the water, and by this means the position of the outlet is ascertained, which is first of all enlarged, and then securely plugged with the clay cement. If the water escapes by one of the galleries, the gallery is abandoned to a certain distance, and endeavours are made with the cement to repress the passage of the water as much as possible. If this fails, however, it becomes necessary to open another gallery, and this is the most difficult task which the miners are called upon to perform. In executing this work they are obliged to divest themselves of every article of dress; as, without this precaution, their clothing would absorb a strong saline composition, which would render it hard and brittle, and cause it to tear the skin. I could not think without compassion of these unfortunate men being thus employed for nine hours a day for so small a recompense as twelve kreutzers (4d. or 4½d.). The men are relieved every three or four hours when thus occupied; and from the hardships they undergo they are not long-lived.

"When the water in the chambers is sufficiently impregnated, it is drawn off. When it is entirely withdrawn, the ceiling is found to have increased about two feet in height; but at the same time the floor is raised two feet by the fallen materials. By this means the necessary degree of thickness is maintained between one chamber and another. Two chambers, situated one above another, are by this process in a gradual course of ascension, so that the lower one occupies the same elevation, in about eight or nine years, which was previously held by the one above it. The saline matter, of which the ceiling is composed, is dissolved, and the other parts are deposited on the floors. The materials thus deposited, although destitute of any saline particles, in the course of time acquire the qualities of rock-salt—a process which promises to render the mountain at Hallein a perpetual source of riches.

"Care is always taken that two neighbouring chambers are not placed on the same level, as the lateral pressure of the water might open a communication between them. When a chamber has been made use of, it is necessary to raise the gallery leading to it, the deposits which have taken place having made the floor about two feet higher than before. On this account, a chamber is only used once in three years.

"A remarkable instance of the growth of a saline rock may be seen at Hallein. In forty years it has encroached about three feet on each side of the gallery, a wooden trough, which runs through the centre, offering a resistance to it in that part which it has been unable to overcome. Each of the galleries, and the aperture by which it is entered, has its separate name, as well as each chamber. The gallery named Wolf Diedrich is so called after one of the prelates who filled the archiepiscopal see of Salzburg, a man of great firmness of character and strength of purpose, as will be seen by the following account of the Wolf Diedrich gallery, which was dug in a part of the mountain which had not previously been penetrated. This gallery was absolutely necessary as an outlet to the water after it had become impregnated with salt, but the only side of the mountain on which it could be executed consisted of the hardest description of marble or granite, and, according to the plan of Wolf Diedrich, it was necessary to penetrate through 1578 yards of this material. Objections were made on the ground of the expense of such an undertaking, and its probable impracticability; but he persisted in spite of these unfavourable opinions. The ordinary implements being found of a temper too soft for the purpose, he caused them to be made of steel,

but still they only struck from the rock particles as small as dust. Wolf Diedrich hoped with all the strength of perseverance. 'If we only succeed in obtaining dust,' he said, 'we shall in time penetrate into the heart of the mountain.' The work was carried on in opposite directions, one party commencing on the outside of the mountain, and the other in its interior, and was continued in this manner during fifty years. The mountain engineers who directed the labours of the workmen, guided their course with such precision, that the two passages opened into each other at the place appointed for their junction. There was, however, some error in the levelling, arising from their having neglected the rules on which they had at first proceeded, and being guided, on the near termination of the work, by the sound of their tools. The sound deceived them, and the error which they made is still visible. This gallery is about a yard broad, and nearly five feet high. It is divided into sixteen stations, where recesses are made, into which, when two *wursts* meet, one of them can be withdrawn to allow room for the other to pass. The inclination of the gallery is about an inch in two yards.

"We were afterwards conducted into a chamber, the walls, floor, and ceiling of which consisted entirely of salt. Fifteen of us entered this apartment, the appearance of which, when illuminated by our torches, was very extraordinary. This is a sort of council chamber of the miners, where the superintendents are received when they pay their annual visit.

"The following is the extent of the mine:—length, 2012 yards; depth, 314 yards. The expenses of maintaining it in a proper state for working are not great, owing chiefly to the wood which is made use of becoming so thoroughly impregnated with salt as not to require renewal. The pernicious gases which are found in coal and other pits, are occasionally generated in these works, but not to such an extent as to produce disastrous consequences. The water at times occasions considerable damage.

"We spent three hours in the heart of the mountain; the air is neither hot nor cold, but of a mild and equable temperature. We proceeded out of the mine by the marble gallery of Wolf Diedrich, seated on a *wurst* drawn by the miners."

From the following description it will be seen that there is an efficacious mode of obtaining salt from salt water, by evaporation produced through the agency of artificial heat. In Scotland, this method has been pursued from a very remote period, and to an extent probably unequalled in any other country. Records are still in existence attesting the endowment of abbeys with salt-pans, some of them referring to a period as early as the twelfth century: the abbey of Holyrood, for instance, was endowed by David I. with the salt-pan of Airth, near the head of the Frith of Forth, along the shores of which noble river the chief salt-pans are still found. The mode of manufacture is said to have been greatly improved during the reign of Mary Queen of Scotland, by the attendants whom Mary brought with her from France, and who received in consequence an exclusive privilege for the production of the commodity, which was continued until the reign of Charles II. At two different periods the Scottish salt manufacture has received great injury; the first at the time of the Union, when the duties levied in both countries were equalized (the ruins of salt-pans scattered along the whole coast of Fife yet attest the effects of that measure); and the second, when the duties were entirely repealed, about twenty years ago, in consequence of which many important works were relinquished. We have now to describe the mode of manufacture.

Near the shore, in a suitable spot, is erected a long and low building, divided into two parts—the one called the fire-house, intended to shelter the workmen and to contain the fuel required; the other, known as the boiling-house, fitted for the reception of the pan in which the brine is contained during evaporation, and for the furnace below. The pan is of an oblong form, commonly measuring about fifteen feet in length, twelve in breadth, and in depth about fifteen inches. The material is generally wrought-iron, but the sides are sometimes of lead, as the iron is apt to oxidize. A walk five or six feet in breadth extends on each side of the pan, for the accommodation of the workmen who assist in the operations. The roof of the saltern (as the building is called), which is partly open to allow of the escape of the steam, is fastened with pegs of wood, as iron nails would quickly be destroyed by the vapour. Near to the saltern is a shed containing the cistern, which is fixed at such a height as to allow the salt water it holds to run through pipes into the pan. The cistern is filled by means of machinery, which pumps up the sea-water from a well communicating by long pipes with a pool or 'lump' in the shore. It is an object with the workmen to draw the water from a point as far below the surface as possible, as they then find it more impregnated with salt, and therefore requiring less trouble, and involving less expense for firing in the process of evaporation. When the sea-water in the cistern has had sufficient time to settle and deposit its mud and sand, it is allowed to flow into the pan (or pans, for there is generally, in the large works, a range of them extending on both sides of the cistern), and a strong fire is now lighted in the furnace beneath. As soon as the fluid is lukewarm, it is clarified, either by mixing the white of three or four eggs with two or three gallons of water, and pouring the mixture into the pan, or by means of the blood of sheep or oxen. As the water gets still more heated, and approaches to boiling, a frothy scum appears, which is collected into little vessels fixed one at each corner of the pan: after this process, the water speedily becomes clear. Having boiled about four hours, crystals appear on the surface, and the amount of water is seen to be greatly lessened: the pan is now refilled with fresh sea-water, allowed to heat, clarified, and cleared from the scum as before, the whole of the process being exactly repeated, and the same a third and a fourth time: after this the pan is no longer supplied with fresh water, the fire is slackened, and, at the end of ten or twelve hours, a large quantity of salt is found nearly dry at the bottom of the pan. This is now raked together into one or two heaps, in order that the brine may drain off; next it is conveyed in barrows to the store-rooms, and laid in 'drabs,' or wooden troughs with shelving bottoms, to allow what little moisture remains to drain away, and from which it is taken, in three or four days, perfectly fitted for immediate use. Each pan of salt requires in the making about twenty-four hours in the whole, so that only five pans a week can be made. The furnaces, however, are never permitted to cool: when the workmen are about to leave on the Saturday afternoon, they place a small quantity of brine in the pan, which is left to simmer, without attendance, till Monday morning; and the product is the Sunday salt, which was once in such great request in some parts of Scotland, as being much finer than the ordinary 'every-day' salt. The fuel used is small coal, which, by a curious incongruity, is called wood: the origin of this custom may, in all probability, be traced to a period when wood alone was used. Two men attend each salt-pan, one of whom is a sort of drudge to the other. These people are a very peculiar race. In appearance and manners they are not unlike colliers, whom too they resemble in another point, their former state of slavery. Till within the last fifty years or so, the salters were transferred with the works on any change of property, in as positive a manner as the black population in our own colonies prior to the late changes, or as the American slaves at this moment. Their freedom was obtained by an application of the proprietors themselves, a rare and honourable action; but so little did the salters themselves appreciate it, that they exclaimed against the whole affair as nothing more than a petty attempt on the part of the proprietors to relieve themselves of a trifling burden to which they were liable on the marriage of a salter or coalman! We conclude with observing that a great proportion of the salt thus prepared is carried by women, chiefly the wives and other relatives of the salters, to Edinburgh.

From an account published in the 'Penny Magazine' a few years ago, by a writer who had personally witnessed the operations, it will be seen that the "salt-licks" of America differ in character from both the saline sources hitherto described.

Salt-lick, although but another name for salt-spring, is the term commonly applied to those weak, and, in many instances, almost imperceptible springs of water, that are more or less impregnated with salt; and which, in some sections of the

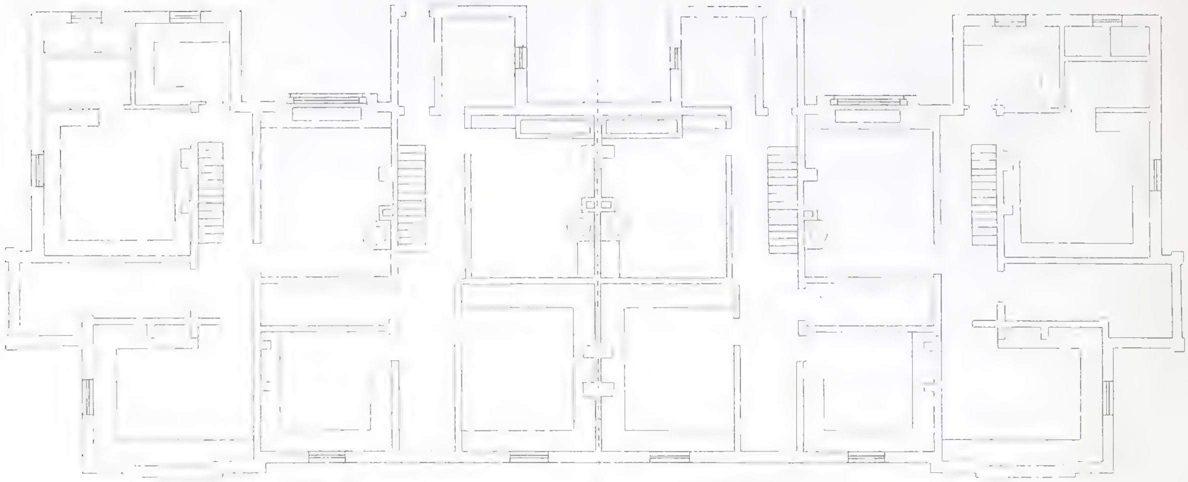


Fig 1

BASEMENT PLAN

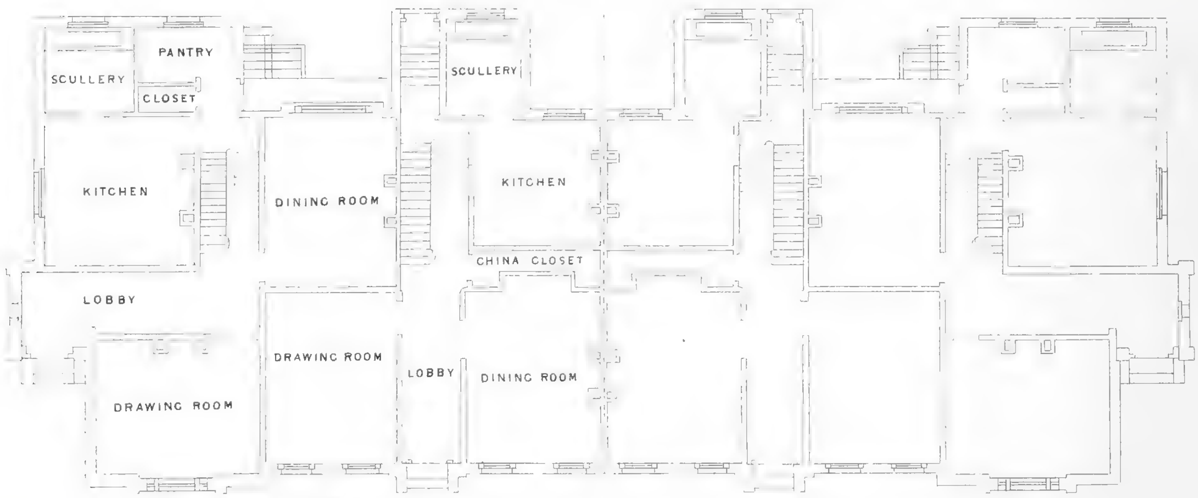


Fig 2

GROUND PLAN

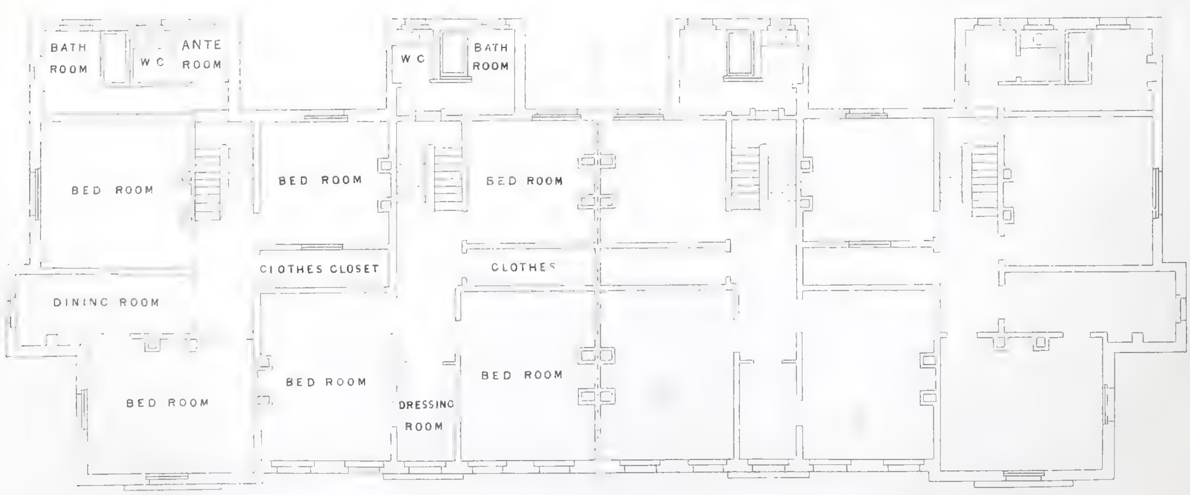


Fig 3

CHAMBER PLAN

SCALE

Fig 1

FRONT ELEVATION

Fig 2

END ELEVATION

continent of America, are commonly met with, particularly in hilly districts, and at a considerable distance from the sea. Salt-licks are frequently called deer-licks by the Americans, from their being much frequented by elk and deer. Indeed, where these springs are weak, and their channels consequently hidden or lost among the almost endless obstructions that impede an infant stream or brooklet in the rough and rude forests, the well-heads of these salt-springs are commonly ascertained by the hunters observing the various deer-tracks leading to one point, whither these animals often repair to browse upon the salt-impregnated herbage (when there happens to be any), or to 'lick' the pebbles at the well-head, or lap the water at the spring. Hence it is that the discovery of a salt-lick by an American hunter is looked upon as a most fortunate circumstance, since it affords him facilities of falling in with and shooting down his game, that are only enjoyed by those who hunt in the vicinity of springs of this nature.

It is generally supposed by those who possess the best means of judging, that salt-springs are more numerous *west* of the extensive range of Alleghany mountains—that is, in the valley of the Ohio, and even through the region west of *that*—than they are to the eastward of the aforesaid mountains, or in a district of country comparatively near to the ocean; and in this it is not difficult to detect the hand of an all-wise governing Providence that hath ordained all things for the best.

The most copious salt-springs that have yet been found out, or rather that have been rendered available to useful purposes, are those near the young and flourishing town of Onandago, in the northern part of the state of New York, rather more than 30 miles north-east of Lake Ontario, and nearly 300 from the Atlantic Ocean. For thirty years these springs have yielded considerable quantities of salt; and the salt-works established there are, in fact, the only extensive and very productive ones throughout the United States. Before these works were in successful operation, and at a period when there were neither canals nor roads through this section of country, salt was a scarce and dear article in all the new settlements situated to the westward; but now that inland communications have been opened, connecting one part of the western country with another, and hence with the older settlements, a barrel of salt weighing 280 lbs. can be purchased on the shores of Lake Huron or Michigan for a sum not exceeding ten shillings sterling. It may be as well to remark that the salt-springs above alluded to are situated in a part of the country by no means mountainous, although somewhat hilly and broken, and at an elevation of a few hundred feet above the level of the sea.

Where salt-licks or weak springs of salt water are known to exist, the owner of such lands (and here the forest is alluded to, where the lands are in a wild state) will sometimes expend considerable sums in boring for salt, apparently upon the supposition that the salt water, which already finds its way to the surface, issues, in all probability, from some capacious reservoir, which, if he could but reach it by boring, might yield a plentiful and never-failing supply.

The process usually adopted by the Americans in boring for salt is somewhat ingenious. Having fixed upon the place where the parties intend to bore, commonly adjacent to the lick or spring, they commence making a perpendicular hole with an instrument called an auger, being shaped exactly like those used by miners in perforating the rocks for the purpose of blasting them, but the diameter being greater, generally about two and a quarter inches. The iron part of the auger, the end of which is faced with steel and brought to a blunt edge, is from three to four feet long, and made in such a manner that a wooden pole of equal diameter can be securely attached to it, in order to give it the desirable length as the work progresses. When the hole has been bored to a moderate depth, a stout upright post with a forked top is firmly fixed in the ground, in the fork of which a long straight pole is placed, where it acts as a lever, this being the principal part of the machinery used in boring. One end of this lever is placed directly over the hole, for the purpose of its being brought down and attached to the upper end of the auger or 'borer,' when, by depressing the contrary extremity of the lever, the auger is raised to the height desired, and by the pulling of a small cord when it is so raised, it instantly becomes detached, and descends into the auger-hole with considerable force. As the depth of the hole increases, other pieces of timber, of suitable size and length, are attached to the 'borer;' and in this way the work is carried on until the necessary depth is attained. One person stands over the hole, whose duty it is to turn the borer one-third or one-half round every time it is raised; a second manages the long lever, and a boy pulls the cord, by which means the borer slips from the end of the elevated lever. In perforating hard rocks, this method of boring is slow work; and as occasional changes of augers, for the purpose of re-sharpening, become necessary, a great deal of trouble is occasioned every time this takes place after the boring has reached the depth of two or three hundred feet, when all the intermediate joinings of the wooden part of the borer have to be undone. These borings are undertaken with the view of reaching some larger or purer body of salt water than that which rises to the surface; and although not generally successful, there are instances where large reservoirs (apparently) have been reached, from which ever afterwards a plentiful supply has risen through the aperture to the surface. These borings are never made with the view of afterwards sinking a shaft; but should water of sufficient saltness be discovered, thin tubes of tin or copper, of the requisite diameter, are inserted in the hole as a *lining*, for the twofold purpose of keeping the hole open, and the water of such springs as may lie between the salt one and the surface of the earth from mingling with, and thereby decreasing the quality of, that which is intended to be turned to a profitable account.

BUILDING ARTS.

CHAPTER V.

In Plates X., XI., and XII., we give a set of drawings of a shop front, with dwelling-house in upper story; forming a practical example of the class now under consideration. Plate X. is the front elevation, and Plates XI. and XII. detached drawings, with description attached.

In Plates XIII. and XIV. we give plans of a cottage (semi-detached), in the Gothic style; forming an example in the third class or division of domestic structures. In Plate XIII., fig. 1 is the front, and fig. 3 the back elevation; fig. 2 the longitudinal section. Half only of the back elevation and longitudinal section is given. In Plate XIV., fig. 1 is the end elevation, fig. 2 the ground plan, and fig. 3 the chamber plan. In the ground plan, *a a* are the livery rooms, 13 feet by 12 feet; *b b* the porch, covering entrances to both houses; *c c* the sculleries, 8 feet by 7 feet 9; *d d* the coal cellars. In the chamber plan, *a a* are the principal bed-rooms, 13 feet by 12; *b b* the girls' bed-room, 8 feet by 7; *c c* the boys' bed-room, 8 feet by 7 feet 9. Under Section I. of our arrangement of subjects, the department of foundations first claims consideration. The word "foundation," as forming part of practical building, embodies two processes: first, the preparation of the ground or soil on which the superstructure rests; and, second, the arrangement of the lower courses of brickwork or masonry forming the walls. Under this view we have first to consider the preparation of the ground or soil. The soils generally met with, in which foundations are to be made, may be divided into two classes. First, *dry* soils, comprising rock, compact clay, stony soils, gravel and sand. Second, *wet* soils, ordinary compressible clay, quicksand, &c. &c.

In making foundations in rock, care should be taken to see that the structure is of sufficient depth to bear the superincumbent weight of material. To receive the foundation courses, the surface must next be levelled carefully throughout, all deep or wide fissures must be filled up with masonry or concrete, and especial care should be taken that the trench is of sufficient depth, so as to remove all the portions of the rock injured by the weather. The surface thus prepared should be perfectly horizontal, so as to receive the pressure of the material resting on it, at right angles to the direction. Where the site of the

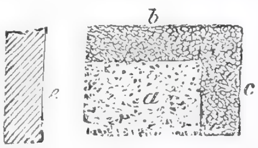
house, on a rocky foundation, slopes much, the bed of the foundation must be cut into steps, or "benched out" as the technical term is, in such a way as to make all the courses of the foundation have a bed perfectly level. Where the inequalities of the ground are so great as to make, in this process of benching out, some portions very much deeper than others, it is recommended by a high authority, to bring the whole of the steps up to the same level throughout, by laying masses of concrete or layers of large stones. The reason for this recommendation is, to prevent the unequal settling of the walls, as the settlement would likely be greatest at the part above where the benching out or step would be deepest.

Where foundations are made in compact clayey soils, care should be taken to protect the soil from the influence of the weather; the majority of clayey soils changing much under atmospheric influences. This is best prevented by placing a layer of concrete in the bed of the foundation before commencing to lay the four courses. In digging the trench for a foundation in clayey soils, it is generally considered to be deep enough if made 12 or 18 inches, the depth, however, to secure a good foundation, should not be less than 30 inches; the great desideratum being to reach the point where the compact soil commences, which is not injured by the atmospheric influences.

Compact stony soils and gravel form the best foundation, and as they generally exhibit no inclination to yield laterally, that is, move away from under the foundation, all that is necessary in such soils, to secure a good foundation bed, is by digging a trench not less than 3 feet deep, and laying it out perfectly level. Where the soil consists of hard set and compact sand, having little or no tendency to yield laterally, the foundation may be made as in the case of gravelly soils.

The danger to be apprehended in sandy soils is the displacement of the layer, by moving laterally from under the foundation; a platform of wood or planking on which to lay the courses is generally recommended; this being confined on each side by walls of masonry or brickwork; this platform is also considered to act beneficially, by distributing the weight of the superincumbent material equally over the foundation beds. Some danger of irregular settlement is, however, apt to arise from this practice, as the wood is apt to decay unequally, and giving way, cause settlement above that part. The safest plan to adopt is that figured in the following diagram (fig. 1), where *a* is supposed to represent the sandy soil; a layer of concrete or beton, *b*, is placed above this, which is levelled carefully to receive the lower courses of masonry or brickwork. To prevent the lateral displacement of the sand, trenches as *e* are cut in each side to some depth below the level of the beton, *b*, and these trenches filled up with masonry or brickwork, or layers of beton or concrete, as *c*.

Fig. 1.



Where the soil is wet, soft, and yielding, lateral displacement is prevented by enclosing the whole area of the foundation with wooden piles driven closely together, the heads being sawn off to a level, and a layer of beton placed over the whole of the foundation bed, the heads of the piles, and extending to some distance over the surrounding soil.

Fig. 2.

In some cases, the bearing soil lies beneath a stratum of soft yielding soil. A method generally adopted to secure a good foundation in this case is, to drive piles into the area of the foundation, as close as they can be driven; to effect this, the distance from centre to centre of the piles should be about 30 inches. After the piles are driven, they must be sawn off to a level, and the platform prepared in which the masonry is to rest. This platform is generally prepared as follows. Let *a'*, fig. 2, represent the outer row of piles; a beam, termed a "capping," is placed over the top of these, and firmly secured by a trenail passing through the capping to each pile pierced beneath. Beams, *c c*, termed "string pieces," are then placed across each row of piles at right angles to the line of capping; the ends of these resting on the capping, to which they are attached by a proper joint and trenail fastening. "Cross pieces" are then placed over the heads of each row of piles at right angles to the line of string pieces, and parallel to the "capping." The string pieces and cross pieces are connected together by the joint known as the "half lap," by which the surfaces of each are brought to the same level. The timber thus arranged, and termed a "grillage," receive the platform in which the courses of masonry rest. This platform is made of planks, the ends of which rest in the capping, and they are secured by trenails, both to this and to the cross and string pieces. The ends of the planks rest in a rebate made in the inner face of the capping, the upper surface of the planks being flush with that of the capping; to admit of this, it follows that the string and cross pieces are so much less in depth than the capping as the thickness of the planking.

In cases such as the above, a method of securing a good foundation by sand is fast coming into repute. The modes adopted are two in number. In the first, a trench is dug, with sides sloping upwards; a layer of sand is laid along the level bottom of this trench, 9 or 10 inches in depth, and firmly bedded and settled by ramming. The trench should be of such a depth as to reach the solid ground, and the layers of sand sufficiently thick to allow of the lower courses, when built, reaching to a point a distance below the level of the surrounding ground. The top of the upper stratum of sand should be protected by a layer of concrete, in which the foundation course is laid. In fig. 3, *a a* the layers of sand in the trench; *b*, the concrete; *c*, the lower course. The spaces, *e*, may be well rammed in with compact clay, or filled up with concrete. As in some soils the water would fill the trench, the sand is used in piles. Short piles are driven into the soil and withdrawn, the holes being immediately filled with sand, slightly moistened

Fig. 3.

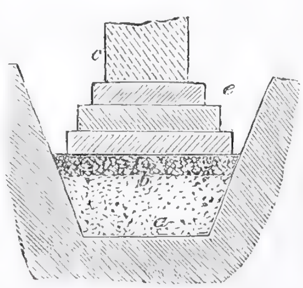
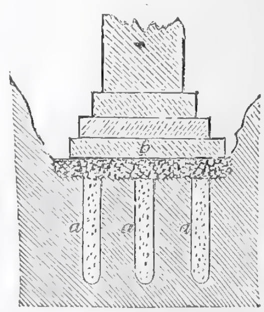


Fig. 4.



to enable it to be rammed close. The piles should be as close as possible. Sand possesses many advantages when used in this way. Wood-piling can only exert a vertical pressure, but sand, possessing some of the properties of a fluid, exerts lateral pressure, as well as vertical; the pressure thus exerted in the sides of the foundation trench relieving or lessening that in the bottom. In fig. 4 this method of sand piling is shown: *a a*, the sand piles; *b*, the lower foundation courses. This method is, of course, not eligible where the soil is very yielding or marshy; the sand having a tendency to exert a lateral pressure as above stated, will ooze out at the sides. In soils of this very soft nature, short piles, from 6 to 12 feet long, are driven into the ground as close as possible; the area over which this is done being much greater than the actual area of the foundation. The piles are then levelled, and a layer of beton applied in place of sand; a thick layer of compact clay may be hard rammed on the top of the piles, each layer about 9 or 10 inches deep, well rammed before the succeeding one is put down.

In laying beton in the bed of a foundation, it should be placed in layers of from 9 to 10 inches thick, and well rammed, till the mortar collects on the top. Where water rises through the bottom of the trench, the beton should be laid on canvas made impermeable to water. Where so much water collects in the trench as to impede materially the operations, the only effectual way to obviate the difficulty is, to drive a row of sheeting piles on each side of the trench, digging a narrow trench outside these, and filling it up with clay, hard rammed. In laying beton or concrete where one layer cannot be finished, a set-off should be made at the left-off end, to which the next portion laid down will " bond," as in fig. 5.

Fig. 5.

Foundation trenches in good soils may here and there present bad parts of a yielding or compressible nature; in this case, the best method is to dig out the bad parts until good soil is met with, filling up the holes thus made with sand.

In a soil of a comparatively dry earth, an excellent foundation may be obtained for small structures, by filling the trench with hard-rammed layers of small broken stones, gravel, &c. The more compact the layers are rammed the better, and the trench should not be less than 30 inches deep, and of a breadth considerably greater than that of the lower course of masonry or brickwork.

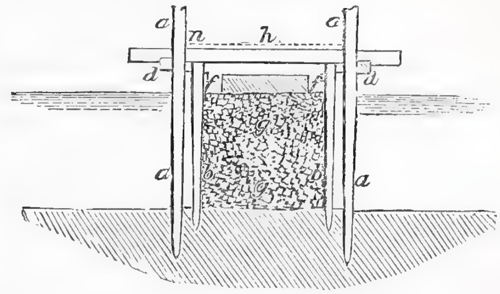
We have now to offer a few remarks on the construction of foundations under water. Where the depth of water is inconsiderable, from 2 to 4 feet, and stagnant, the simplest method is to throw in masses of stone, leaving them to arrange themselves. Where the superincumbent wall is not heavy, this method will be effectual; although it is not to be recommended in cases where the water is a quick-running one, and the soil forming the bottom a light one, as, in this case, the soil will be gradually washed away from under the stones, and irregular settlement will take place.

The French method of laying beton in masses or blocks, is well adapted for foundations in shallow water, where the ground is of a rocky nature. This plan consists in placing a large box with enclosing sides only; this caisson is lined with impermeable cloth, which, adapting itself to the irregularities of the rock in which the caisson rests, prevents the beton, on being laid, being prejudicially acted upon by the water. The beton is lowered into the caisson in a box provided with a moveable bottom; by this means the beton is deposited at the point where it is required, thus obviating the necessity of dropping it through the water, which operation is apt to wash the lime out of it. On the successive blocks or layers reaching the level of the surface of the water, the operation is suspended until the beton sets hard; the sides of the caisson are then removed, exposing the mass of beton on which the superstructure is raised. The box or caisson can be used again and again, until the necessary length of foundation is made.

Where the soil is of soft mud or earth, and the water stagnant, and from 3 to 4 feet deep only, the area of the foundation should be enclosed with a dam of adhesive clay, the water pumped out of the space thus formed, and the foundation trench dug and prepared in any of the methods we have already described for foundations under ordinary circumstances. Where the foundation courses are built up above the level of the water, the sides of the dam must be removed. Where this dam cannot be adopted, a simple species of cofferdam may be constructed, by driving in a row of sheeting piles, enclosing the area, and lining these with strong planking, well caulked; the water may be pumped out of the space thus enclosed, and the foundation made in the usual way. If the foundation soil, in this case, is of soft mud, it should be scooped out for some distance, and the space filled with small stones well rammed, in which the foundation should be placed.

For forming foundations in running water, the form of cofferdam used is exemplified in fig. 6. A row of straight piles, *a a*, are driven round the area to be enclosed, the centre lines being about 4 feet apart. The sheeting piles, *b b*, are driven in juxtaposition. The main piles, *a a*, are connected by a horizontal beam, termed a " string piece" or wall, *d d*, placed a foot or two above the water line, and are notched and bolted to each pile. The wall pieces, *f f*, of the row of sheeting piles, *b b*, are placed towards the space enclosed. Interior " piles," *e e*, are placed in the inside of the main piles, *a a*, to serve as supports for the sheeting piles, *b b*. Cross pieces, *c c*, connect the string pieces, and prevent the bulging out of the piles from the internal pressure. The planking is also laid on these as shown by the dotted line in fig. 6. The space between the

Fig. 6.



inner and outer row of piles is filled up clay—termed puddling —well rammed. To prevent the pressure of this against the piles, when the interior space is emptied of water, intermediate string pieces may be put between the rows, these being fixed on the interior row of piles before the sheeting piles are driven. The prevention of leakage under the dam is the principal difficulty to be contended with in the construction of cofferdams. This may be provided against, in a great measure, by using sand with the clay for puddling between the rows of piles, care being taken to take out all extraneous matter, as mud, before ramming the puddling.

Foundations in running water should be protected from the action of the current, by throwing in, as generally adopted, loose masses of stone of sufficient weight.

For artificial foundations in bad soils, concrete seems, by all authorities, to be considered the best. Under the proper division will be found remarks as to the best method of preparing this.

Under the third and fourth division of our papers, we shall give " notes" on the arrangement and construction of the " footings" of brick and stone work; we conclude the present department by giving the following important hint on the subject of foundation, by an eminently practical authority.* " In the case of a foundation, partly natural and partly artificial, the utmost care and circumspection are required to avoid unsightly fractures in the superstructure, and it cannot be too strongly impressed on the mind of the reader, that it is not an unyielding, but a uniformly yielding foundation that is required; and that it is not the amount, so much as the inequality of the settlement, that does the mischief." (P. 3.)

DRAINAGE.

We now come to the important subject of Drainage. House drainage is divisible into two branches, both equally important. 1. The drainage of the site for the prevention of damp. 2. Sewage drainage, or that which has for its end the removal of the excretæ, and the refuse of domestic preparations, from the neighbourhood of the dwelling to the final place of deposit.

That the drainage of the site on which a house is to be built, is considered of slight importance—if considered at all, which, in many instances, we believe to be the real state of the case—we have only to look around us to have proof of the fact. Damp sets the unmistakable seal of its presence in the walls of two many of our dwelling-places. Indeed, so little is the site drainage thought of, that, when drainage is mentioned, it is rarely meant to convey anything more than that the sewage is removed from the neighbourhood of the dwelling. So generally is simple water drainage neglected, that it appears, from the late sanitary investigations, that in town districts which are called drained, the foundations of the houses are very generally damp, from the retentiveness of the water-bearing power of the

* Rudiments of the Art of Building. By E. Dobson, Weale. 1s.

soil in which they are built. Water rising from a damp foundation by absorption, renders the floors and the walls damp in proportion to the absorbent nature of the materials of which they are constructed. When experienced medical officers see rows of houses springing up on a foundation of deep retentive clay, inefficiently drained, they foretell the certain appearance among the inhabitants, of catarrh, rheumatism, scrofula, and other diseases; the consequences of an excessive damp, which break out more extensively, and in severer forms, in the cottages of the poor, who have scanty means of purchasing the larger quantities of fuel, and of obtaining the other appliances by which the rich partly counteract the effects of dampness. Excess of moisture is often rendered visible in the shape of mist or fog, particularly towards evening. An intelligent medical officer took a member of the sanitary commission to an elevated spot, from which his district could be seen. It being in the evening, level white mist could be distinguished over a large portion of the district. "These mists," said the officer, "exactly mark out and cover the seats of disease for which my attendance is required. Beyond these mists I have rarely any cases to attend, but midwifery cases and accidents." Efficient drainage causes the removal, or, at least, a great diminution of such mists, and a proportionate abatement of the diseases generated or aggravated by dampness. After houses built in the manner described have been inhabited for some time, and especially if crowded, "fevers of a typhoid type are added to the preceding list of diseases, in consequence of emanations from privies and cesspools. The poisonous gases, the product of decomposing animal and vegetable matter, are mixed with the watery vapours arising from the excessive damp (such vapours being now recognised as the common vehicle for the diffusion of the more subtile noxious gases), and both are inhaled night and day by the residents of these unwholesome houses. A further consequence of the constant inhalation of these noxious gases, which have an extremely depressing effect, is inducing the habitual use of fermented liquors, ardent spirits, or other stimulants, by which a temporary relief from the feeling of oppression is obtained."*

Such is a fair statement of the physical and moral evils resulting from damp sites; viewed pecuniarily, the evil is also striking enough—more especially where the houses are proposed to be built on what may be called villa land in suburban neighbourhoods. It is quite obvious that the more salubrious a district is, the higher the price will be obtained for building sites. Moisture in excess, not only affects the building itself, but influences the climate of the district in which it may be placed, both as regards dryness and temperature. The following are given by the Sanitary Commissioners as the effects of an excess of moisture:—1. It is a cause of fogs and damp, even on land not evidently wet. 2. Dampness serves as the medium of conveyance for any decomposing matter that may be evolved, and adds to the injurious effects of such matter in the air; in other words, the excess of moisture may be said to increase or aggravate atmospheric impurity. 3. The evaporation of the surplus moisture lowers temperature, produces chills, and creates or aggravates the sudden and injurious changes or fluctuations of temperature, by which health is injured. By the removal of every inch in depth of water carried off by drains, which would otherwise evaporate, as much heat is saved per acre as would elevate eleven thousand million cubic feet of air one degree in temperature. But not only is the temperature of the atmosphere reduced by the presence of an excess of moisture, but the dew point is raised, in consequence of water being evaporated which might otherwise be drained off; the formation of dews and mists is thus encouraged, and the dampness resulting is perhaps even more opposed to personal comfort than the reduction of temperature. The truth, then, of the farmer's statement, which might, in one point of view, be considered somewhat absurd, is obvious enough, that after certain drainage works were completed, he could go out at night without his great-coat, while before he could not, so that the drainage made "the difference of a great-coat to him."

Having thus shown the importance of the drainage of the site for the prevention of damp, it remains for us to point out the method by which this desideratum can be effected.

The difference between the drains used for conveying the surplus water from the soil, and those for the sewage, is simply this: in the latter, it is an essential point to be attended to, that throughout their whole length they must be impermeable, that is, water-tight, so as to allow no passage of their contents to the soil in which they are embedded; while in the former they must be permeable, that is, capable of admitting to their interior the surplus water of the soil through which they pass, conveying it away to the proper outfall. Site drainage, therefore, comes under the same class of operations as land drainage for agricultural purposes, the only difference being, that, in the former the drains are made at a greater depth, and laid more closely together than the latter.

The "outfall" having been determined on, which, in suburban districts, will probably be the open ditch alongside the road, the next point is the laying out of the drains. To aid in this, we here give the opinion of eminent drainage engineers as to the width apart and depth of drains for different classes of soils. It is but right, however, to state that great difference of opinion exists on this point; that deep drains are the best, seems, however, to be pretty generally conceded. Mr. Hammard found 4 feet drains, at a distance of 50 feet asunder, efficient in soils of varied texture, not uniform clays. Mr. Smith, of Denniston, states that drains from 2 to 3 feet deep, at a distance of 18 to 24 feet, have been found to effect thorough drainage. Mr. Scott states that "drains are generally 3 to 5 feet deep, and from 20 to 50 feet apart; in strong retentive pure clays, from 3 to 4 feet deep, placed at distances of from 20 to 36 feet apart; in porous subsoils, such as gravel or sand, from 4 to 5 feet deep, and 40 to 50 apart." Mr. Maccan states "that the depths and distances of drains are various in relation to the different descriptions of soil. 1. On a thin clay soil and subsoil of great tenacity, drains were formerly 12 to 15 feet apart, and 2 feet deep. That depth increased afterwards to 2½ and 3 feet. Since the Drainage Act came into operation, the distance apart of drains was extended to 21 and 24 feet, the depth to 3½ and 4 feet. Soon after, however, the distance apart was contracted to 16 and 21 feet, the depth remaining the same; and this system now prevails generally in soils of the description named. 2. On a clay soil of less tenacity, having more sand or gravel in its composition, drains are now generally made from 3½ to 4 feet deep, and 21 to 27 feet apart. 3. On soils of greater porosity, with less clay in their composition, and where spring water exists, drains are being made from 4 to 5 feet deep, and from 27 to 40 feet apart. The main drains are generally cut a few inches deeper than the branch drains."

"The question," says another authority, "of the depth of drains is affected by two considerations: first, their permanency; secondly, their efficiency. It is, without doubt, an established fact, that in most soils, shallow drains are choked in the course of time, and in some in a very few years; and an examination into the cause has shown that they have become filled with the fine particles of soil washed down through worm and mole holes, cracks and cavities, &c. On the other hand, deep drains being removed from the active soil, are exempt from such casualties, and thus their permanency secured." The same authority (Mr. Spooner) states, that "in the generality of soils, drains are not safe at a depth of much less than 3 feet, and that they may to greater advantage be laid at a depth varying from that to 4 feet."

Having thus decided on the outfall and the depth and distances of the drain, the next point to be attended to is the giving the drain a gradual and perfectly regular inclination, from their furthest extremity to the point of outfall. From want of attention to this point, drains are frequently inoperative to a great extent. A slight rising in the bed of a drain will interrupt the flow of the "descending water, till it accumulate so high as to be above the level of the rising, which will thus lead to a permanent stagnation, or loss of fall for a certain length of the drain."

A regular descent in the bed of the drain is attained by the use of what are termed "boring rods," the use of which may

* Minutes of Information, collected in respect to Drainage of the Land forming the Sites of Towns and Wall Drainage. Presented to both Houses of Parliament. 1852.

be described as follows:—" Three staffs are made use of, two of them 2 feet long, and the third as much as more than 2 feet as the drain is deep; that is, if the drain is 3 feet 6 inches deep, it must be 5 feet 6 inches long. The staffs are strips of wood, with cross pieces 9 inches long at the end that is to stand uppermost. The two shorter staffs are planted upright, one in the ground on a level with the field at the head of the drain, and the other at the lower end, and a person stands at one of them looking over its top with his eye on a line with the other. A second man then takes the longest staff and holds it upright in the drain, just touching the bottom, and walks along from one end of the drain to the other, keeping it in the upright position. If, when it is moved along, its top always appears in a line with the tops of the other two, as seen by the person looking along the three, the fall of the drain is uniform; but if it rises above this line at any one place, the bottom is too high there, and requires to be reduced; if it falls below the line, the bottom is too low, and must be raised. In this way, the " fall may be rendered perfectly uniform."

The materials used for forming the drains are of various kinds—stones, tiles, and tubes. All authorities seem to agree in holding cylindrical tubes as the best; these varying in size from $1\frac{1}{4}$ to 2 inches diameter. Mr. Parkes prefers to lay them with the collar at the joints, as shown in fig. 7. This method of joining the lengths, secures the drain from the entrance of sand or earthy deposit, &c. Of course, it must be borne in mind that the joints are left free, that is, not made up with cement, in order to allow of the water entering their interior. It is important to remember, also, that too great a slant in drains is injurious, and the water passes so rapidly through them as to drain the land so fast as to wash away very valuable ingredients from the soil. One mode of obviating this difficulty is to make the drains broader, and thus cause the stream of water in them to be shallow, and therefore less rapid in its flow.

The following table by Mr. Parkes will convey an idea of the amount of land drained according to different depths and distances:—

Depth of the drains in feet.	Distances between the drains in feet.	Mass of soil drained per acre in cubic yards.	Mass of soil drained for 1d. in cubic yards.	Surface of soil drained for 1d. in square yards.
2	24	$3,266\frac{1}{2}$	4·1	6·27
3	$33\frac{1}{3}$	4,840	8·93	8·93
4	50	6,453	12·00	8·96

A plan for combining the tubes for the site drainage and the house drainage in one has been proposed, and a sketch of which we give in fig. 8. The lower tube is for the land drainage, the upper for the house. The objections militating against the adoption of such a plan were principally these: that the levels of the two systems of drains, the land and sewage, were rarely the same; that circumstances might require fewer of the one than of the other; and that the situations of the drains might be different.

As a guide to the cost of draining sites of houses of various descriptions, and in conveying much valuable information on a subject of much importance, we give extracts from the report from which we have already quoted, showing the mode and cost of draining the sites of suburban edifices.

In fig. 9 we give the plan of a site, one acre in extent, for detached villa residence. The site of the building deep drained, and the rest of the ground thoroughly drained.

In fig. 10 we give plan of site, one acre in extent, laid out for four semi-detached villas; the sites deep drained, the rest thorough.

In fig. 11 we give the plan of site of (half an acre) two detached villas. The drainage as above.

In fig. 12 we give the plan of site (one acre) for twelve semi-detached cottage villas; the whole thoroughly drained.

In all the plans, the dark broad lines indicate the deep drains, the dotted lines the thorough drains, and the two parallel lines the wall drains.

The estimates are made for light, medium, and heavy soils, and are for the different examples as follows:—

Labour and Materials.	Quantities.	Rate.	Amount.
Example 1st, fig. 9; Light Soils.		s. d.	£ s. d.
Deep (5 feet) drain at per yard,..........	147	0 4	2 9 0
Drain ($1\frac{1}{4}$ in.) pipes at per thousand.......	441	..	0 14 5
Minor ($3\frac{1}{2}$ ft.) drain at per yard,..........	622	0 $2\frac{1}{2}$	6 9 7
Drain (1 in.) pipes at per thousand,......	1866	..	2 6 7
			11 19 7
Rent or rate for twenty years,...........	..	..	0 18 $3\frac{1}{2}$
Medium Soils.			
Deep (5 ft.) drain at per yard,............	147	0 5	3 1 3
Drain ($1\frac{1}{4}$ in.) pipes at per thousand,......	441	..	0 15 5
Minor ($3\frac{1}{2}$ ft.) drain at per yard,..........	622	0 3	7 15 6
Drain (1 in.) pipes at per thousand,......	1866	..	2 6 7
			13 18 9
Rent or rate for twenty years,...........	..	..	1 1 $4\frac{3}{4}$
Heavy Soils.			
Deep (5 ft.) drain at per yard,............	147	0 6	3 14 6
Drain ($1\frac{1}{4}$ in.) pipes at per thousand,......	441	35 0	0 15 5
Minor ($3\frac{1}{2}$ ft.) drain at per yard,..........	622	0 4	10 7 4
Drain (1 in.) pipes at per thousand,......	1866	25 0	2 6 7
			17 3 10
Rent or rate for twenty years,...........	..	..	1 6 $0\frac{1}{4}$
Example 2nd, fig. 10; Light Soils.			
Deep drain at per yard,................	151	0 4	2 10 4
Drain ($1\frac{1}{4}$ in.) pipes at per thousand,......	453	..	0 15 10
Minor drain at per yard,................	495	0 $2\frac{1}{2}$	5 3 $1\frac{1}{2}$
Drain (1 in.) pipes at per thousand,......	1485	..	1 17 2
			10 6 $5\frac{1}{2}$
Rent or rate for twenty years,...........	..	..	0 15 $8\frac{1}{2}$
Ditto per house,......................	..	..	0 3 11
Medium Soils.			
Deep drain at per yard,................	151	0 5	3 2 11
Drain ($1\frac{1}{4}$ in.) pipes at per thousand,......	453	..	0 15 10
Minor drains at per yard,...............	495	0 3	6 3 9
Drain (1 in.) pipes at per thousand,......	1485	..	1 17 2
			11 19 8
Rent or rate for twenty years,...........	..	..	0 18 3
Ditto per house,......................	..	..	0 4 $6\frac{3}{4}$
Heavy Soils.			
Deep drain at per yard,................	151	0 6	3 15 6
Drain ($1\frac{1}{4}$ in.) pipes at per thousand.......	453	35 0	0 15 10
Minor drain at per yard,................	495	0 4	8 5 0
Drain (1 in.) pipes at per thousand,......	1485	25 0	1 17 2
			14 13 6
Rent or rate for twenty years,...........	..	..	1 2 $4\frac{1}{4}$
Ditto per house,......................	..	..	0 5 7
Example 3rd, fig. 11; Light Soils.			
Deep drain at per yard,................	161	0 4	2 13 8
Drain ($1\frac{1}{4}$ in.) pipes at per thousand,......	483	..	0 16 10
Minor drain at per yard,................	242	0 $2\frac{1}{2}$	2 10 5
Drain (1 in.) pipes at per thousand,......	726	..	0 18 1
			6 19 0
Rent or rate for twenty years,...........	..	..	0 10 8
Ditto per house,......................	..	..	0 5 4
Medium Soils.			
Deep drain at per yard,................	161	0 5	3 7 1
Drain ($1\frac{1}{4}$ in.) pipes at per thousand,......	483	..	0 16 10
Minor drain at per yard,................	242	0 3	3 0 6
Drain (1 in.) pipes at per thousand,......	726	..	0 18 1
			8 2 6
Rent or rate for twenty years,...........	..	..	0 12 $3\frac{1}{4}$
Ditto per house,......................	..	..	0 6 $1\frac{1}{2}$

Labour and Materials.	Quantities.	Rate.		Amount.		
Heavy Soils.		s.	d.	£	s.	d.
Deep drain at per yard,....................	161	6	0	4	0	6
Drain (1¼ in.) pipes at per thousand,......	483	35	0	0	16	10
Minor drain at per yard,..................	242	0	4	4	0	8
Drain (1 in.) pipes at per thousand,........	726	35	0	0	18	1
				9	16	1
Rent or rate for twenty years,...........	..		..	0	14	11½
Ditto per house,..........................	..		..	0	7	6¾
Example 4th, fig. 12; *Light Soils.*						
Deep drain at per yard,....................	484	0	4	8	1	4
Drain pipes at per thousand,.............	1452		..	2	10	9½
Minor drain at per yard,..................	147	0	2½	1	10	7
Drain pipes at per thousand,.............	441		..	0	11	0
				12	13	8½
Rent or rate for twenty years,...........	..		..	0	19	4¼
Ditto per house,..........................	..		..	0	1	7½
Medium Soils.						
Deep drains at per yard,..................	484	0	5	10	1	9
Drain pipes at per thousand,.............	1452		..	2	10	9½
Minor drain at per yard,..................	147	0	3	1	16	9
Drain pipes at per thousand,.............	441		..	0	11	0
				15	0	3½
Rent or rate for twenty years,...........	..		..	1	2	10½
Ditto per house,..........................	..		..	0	1	11
Heavy Soils.						
Deep drain at per yard,....................	484	0	6	12	2	0
Drain pipes at per thousand,.............	1452	35	0	2	10	9½
Minor drain at per yard,..................	147	0	4	2	9	0
Drain pipes at per thousand,.............	441	25	0	0	11	0
				17	12	9½
Rent or rate for twenty years,...........	..		..	1	6	11
Ditto per house,..........................	..		..	.0	2	3

We finish this department by giving a table by which the cost of making drains may be estimated.

In calculating the expense of forming drains or ditches, one of the chief items is the quantity of earth that has to be thrown out, which depends on the size of the drain. The cost of the labour will necessarily increase with the weight of earth that has to be removed; hence it is convenient to know the solid content, or the number of cubic yards of cutting in a drain of any given dimensions. This is found by multiplying together the length, depth, and mean width of the drain. Thus, if a drain is 300 yards long, and the cutting 3 feet deep, 20 inches wide at the top, and 4 inches wide at the bottom, the mean width would be 12 inches (or half the sum of 20 and 4); and if we multiply 100, the length by the depth in yards, and by ⅓d the mean width in yards, the product will be 100 cubic yards. The following will serve to facilitate such calculations.

Table showing the number of cubic yards of earth in each rod (5½ yards in length), in drains or ditches of various dimensions:—

Depth.	Mean Width.											
Inch	7 in.	8 in.	9 in.	10 in	11 in.	12 in	13 in.	14 in.	15 in.	16 in.	17 in.	18 in.
30	·89	1·02	1·146	1·27	1·40	1·53	1·655	1·78	1·91	2·04	2·164	2·29
33	·98	1·12	1·26	1 40	1·54	1·68	1·82	1·96	2·10	2·24	2 38	2·52
36	1·07	1·22	1·375	1·53	1·68	1·83	1·986	2·14	2·29	2·244	2·60	2·75
39	1·16	1·324	1·49	1·655	1.82	1·986	2·15	2·32	2·48	2·65	2 81	2·98
42	1·25	1·426	1·604	1·78	1·96	2·14	2·32	2·495	2·674	2·85	3.03	3·21
45	1·34	1·53	1·72	1·91	2·10	2·29	2·48	2·67	2·865	3·055	3·246	3·438
48	1·426	1·63	1·833	2·04	2·24	2·444	2·65	2·85	3·056	3 26	3·46	3·667
51	1·515	1.73	1·95	2·164	2·38	2·60	2·81	3·03	3·25	3·46	83·6	3·896
54	1·604	1·83	2·06	2·29	2 52	2·75	2·98	3·20	3·44	3 666	3·895	4·125
57	1·69	1·935	2·18	2·42	2·66	2·90	3·14	43·38	63·63	3 87	4·11	4 354
60	1·78	2·036	2·29	2·546	2·80	3 056	3·31	3·564	3·82	4·074	4·33	4·584

Along the top of the table is placed the mean widths in inches, and on the left hand side the depths of the drains extending from 30 inches to 5 feet. The numbers in the body of the table express cubic yards and decimals of a yard.

EXPERIMENTS ON GUNPOWDER, AND THE ACTION OF SHOT ON IRON TARGETS.

The report of experiments on gunpowder, made at Washington Arsenal, by Captain Alfred Mordecai, of the United States Ordnance Department, embodies the results of many thousands of accurate experiments made by that gentleman, under government authority, with instruments constructed in such a manner as to ensure perfect accuracy. Having had the satisfaction of inspecting the instruments, and of hearing from Capt. Mordecai an account of the methods of experimenting, we can speak of them with the greater certainty. The force of gunpowder, since the time of Hutton and the French experimenters, has been calculated by means of the *balistic pendulum* and of a *gun pendulum.* The *gun* (in these experiments a twenty-four and a thirty-two pounder) is suspended in an iron frame, hung on knife edges of hardened steel, like a balance beam, the whole supported (a load of 10,500 lb.) on massive stone pillars. The recoil is measured on a limb of brass, having a curve, of which the frame work and the gun are the radius, and graduated to read to seconds by means of a vernier which is moved by the recoil, and retained at the point of greatest vibration by a slight spring. When the gun is adjusted and at rest, its axis is a horizontal line, and the vernier stands at zero on the scale.

At a distance of only fifty-five feet (between the centres) is inserted the *pendulum block* for receiving the shot and measuring its velocity. This *pendulum* is a counterpart to the gun, as regards its mode of suspension and motion, which is also measured in like manner on a graduated arc. This "*block*" as it is called, resembles a mortar or wide howitzer, with a bore of four and a half feet deep and fifteen inches calibre, and filled with leathern bags of sand, and a bedding of lead. This block, the frame and counterpoise weights, weighed 9,358 lbs., and was suspended so as to hang when at rest, with its axis in one and the same line as the axis of the gun. When prepared for use, the aperture of the pendulum block was covered by a sheet of lead, which served to make the deviation of the ball from a right line, by the hole which was pierced in it. This deviation was found to be very slight.

It seems, to a person unaccustomed to such experiments, a rather daring attempt to fire a thirty-two pound shot, at the distance of only 50 feet, in the mouth of another gun. But that velocity which, left unrestrained, would serve to carry the shot for miles, is in this apparatus restrained within the range of a few feet, and imparts only a moderate motion on the great mass of matter on which it impinges, which can be wholly and accurately estimated. Capt. Mordecai remarks, that "an observer, placed in such a position as to see the face of the block unobscured by the smoke of the gun, perceives, at the moment of impact, a circle of *reddish white flame* surrounding the hole made by the ball." He supposes "that this flame may be produced by the combustion of minute particles of iron and lead ignited by friction." He further remarks, that "in firing a thirty-two pound ball into the pendulum block with a charge of eight pounds, the sand immediately before the ball was compressed into a solid mass, forming an imperfect sandstone sufficiently firm to bear handling. A specimen is still preserved in that state, after a lapse of more than eighteen months." This sand, when examined, was found quite free from any calcareous cement. An apparatus of quite similar structure, on a proportionate scale was used for muskets. In these experiments powder from a great number of manufactories, and of great variety of composition, grain, and finish, was tested. The elements for calculating the strength of gunpowder, obtained by these experiments, were resolved by the formulæ of Hutton and those which more recently have been employed by the French at Metz. This portion of the labour is performed with the accuracy and skill which characterise all the highly educated officers from West Point Academy. Captain Mordecai concludes from the results of his experiments, that the only reliable mode of proving the strength of gunpowder is to test it, with service charges, in the arms for which it is designed.

In the twenty-four pounder gun, new cannon powder should give, with a charge of one-fourth the weight of the ball, an initial velocity of not less than sixteen hundred feet, to a ball of medium size and windage.

The initial velocity of the musket ball, of 0·05 in windage, with a charge of one hundred and twenty grains, should be—

With new musket powder not less than	1,500 feet.
" " rifle " " "	1,600 "
" fine sporting " " "	1,800 "

The common eprouvettes are of no value as instruments for determining the relative force of different kinds of gunpowder.

The proportions used in the best American gunpowder, 76·14·10, and the English 75·15·10, appear to be favourable to the strength of gunpowder. The best mode of manufacture is in what is called the cylinder mills under heavy rollers, and this process alone is considered capable of making good sporting powder. The English have employed this process for fifty years, but the French still use the old method, by stamping or pounding. The "*gravimetric density*" should not be less than 850, or more than 920. The charge for cannon for all ordinary purposes should be one-fourth. No purpose, even breaching a battery, requires more than one-third the weight of the ball. For small arms the following charges are proposed . for the percussion musket, 110 grains ; the percussion rifle, 75 grains : the percussion pistol, 30 grains of rifle powder. It is proposed that musket and rifle balls should be made by compression, instead of casting, as at present.

To these American experiments may be subjoined the following, which were undertaken at the Arsenal, Woolwich, to determine the effect of shot upon the hull of an iron vessel, and also with the view of providing means for stopping the passage of water through a shot-hole near the water line. This latter object was sought to be effected by packings of various kinds fixed behind the sheathing-plates, which by their elasticity will close over the hole after the passage of the shot through them.

The gun used in these experiments was a 32-pounder, placed at the distance of 30 yards from the targets, and was loaded with the full charge of 10 lbs. of powder, and also with 2 lbs. and 1 lb. to produce the effect of a spent shot.

The initial velocity of the ball with the full charge was about 1800 feet per second, and with a 2 lbs. charge, 1000 feet. The diameter of the shot was 6 inches.

Target, No. 1, was made of three thickness of $\frac{1}{2}$-inch plates riveted together by double rows of rivets arranged in rectangles of 24 inches $\times$ 14 inches. A shot fired through this with the full charge made a clean hole of its own diameter, with very little tearing or raising of the edges, and no rivet head started near the hole. The round piece cut out by the shot was broken into angular splinters of one, two, or three inches long, which diverged from the hole in all directions, and with great violence. When the full charge was used, no disturbance in the plate or the rivets round the hole was observable.

This target was not stiffened with angle-irons.

No lining was placed behind this target.

Target, No. 2, was formed of single $\frac{1}{2}$-inch plates, flush jointed, single-riveted, with frames 9 inches deep, attached by double angle irons 6 inches $\times$ 3 inches. The frames were 33 inches apart.

One half of this target was lined at the back with pure india-rubber, and the other half with a mixture of india-rubber and cork-dust, containing 25 per cent. of the latter by weight; it was 12 inches thick. These linings were held to the sheathing by 1-inch screw-bolts with square heads outside, and nuts with washers of $\frac{5}{16}$-inch plate, 8 inches square inside, the washers completely covering the elastic lining. The bolts were in the centre of each square, or 8 inches apart.

Through the india-rubber and cork-dust five shots were fired, all striking, as was intended, between the heads of the bolts. Two shots with the 10 lb. charge made clean perforations through the outer plate, and passed through the lining without shattering it much, but each shot knocking off four or five of the back plates with great violence. The splinters from the outside plate all passed through the lining, and radiated as before mentioned. After the passage of the shot, the elastic lining closed completely over the hole, so as to become impervious to light and apparently to water.

Several proportions of india-rubber to cork-dust have been tried, but the proportion above mentioned was considered the best. Three other shots were fired through this lining with the 2 lb. charge of powder, and were purposely made to strike within a circle of 12 inches diameter, so that the three holes joined; still the lining closed over the holes so as to exclude light, or prevent the passage of a thin walking-stick through it in any direction, which was considered very satisfactory. Of course a great many of the back-plates, about eight, were torn off.

With the small charge of powder the sheathing-plate suffers much more than with the full charge, the plate being considerably drawn into the hole, raising the edge inside, and stripping off the rivet heads near it. A shot fired with 1 lb. of powder produced this effect in a greater degree, but in all cases the ball seems to carry with it a part of the outside plate torn from the hole, the piece increasing in size with the velocity of the cannon ball.

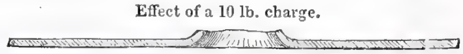
During an experiment with this target, a splinter struck a sentinel on duty at about 200 yards' distance, passing entirely through the calf of his leg. It was a flat piece, about the size of a penny, and must have glanced from the target at a very obtuse angle, and returned by the resistance of the atmosphere to where the man was standing, which was some way in advance of the horizontal line of the target.

A weak shot was passed through the lining of solid india-rubber (twelve inches thick) which completely closed over the hole, apparently excluding the passage of water, and even air. This shot caused a great dislocation of the plates at the back, a number of which were driven off by the breaking of the nuts, consequent on the pressure thrown upon them by the tenacity of the india-rubber. The targets were 6 feet square.

Target, No. 3, was formed of double $\frac{1}{2}$-inch plates riveted together, and no frames. Half of this target was lined with solid india-rubber, 8 inches thick, and held on by screw-bolts and square washers as before. One chief objection to india-rubber as a lining for ships is its great expense. It would be also difficult to *confine* it in warm climates, as it assumes a kind of semi-fluid motion when acted on by its own gravitation. The other half of this target was lined with a mixture of india-rubber and cork-dust, 12 inches thick, held on as before. In this case the cork-dust (which is cork chopped very fine) was in too large a proportion for the india-rubber, and consequently the hole formed by the shot did not close, and the lining itself was very much shattered.

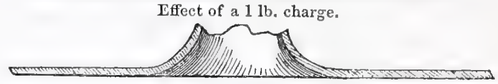
Target, No. 5, was formed of two plates, having a space of 10 inches between them, half of this space being filled in with felt, and half with india-rubber and cork-dust introduced in small pieces through hand-holes cut in the ceiling-plate between the frames (which were 15 inches apart). The outer sheathing-plate was $\frac{5}{8}$-inch thick, and the inner $\frac{5}{16}$-inch. The felt proved of no use in stopping the hole, and by its pressure it tore away a large portion of the ceiling-plate, about 2 square feet, where the ball passed through. This large piece was quite detached from the plate in various fragments, which seem to have broken off quite short. A similar effect was produced in the ceiling-plate by the passage of the ball through the lining of india-rubber and cork-dust, and the latter from being introduced in small pieces by the hand-holes did not close over the hole, and was very much shattered.

Effect of a 10 lb. charge.



Effect of a 2 lb. charge.

Effect of a 1 lb. charge.



It was found that a ball, whatever be its velocity, produced much the same effect upon the elastic lining, although not so with the iron plate, as we have shown. This will be better illustrated by the annexed sketches of the effect produced on the plate by different charges of gunpowder.

IMPROVED BALL-COCK.

THE subjoined figures represent an improved ball-cock, intended to open and shut instantaneously, and which may be used with a water meter.

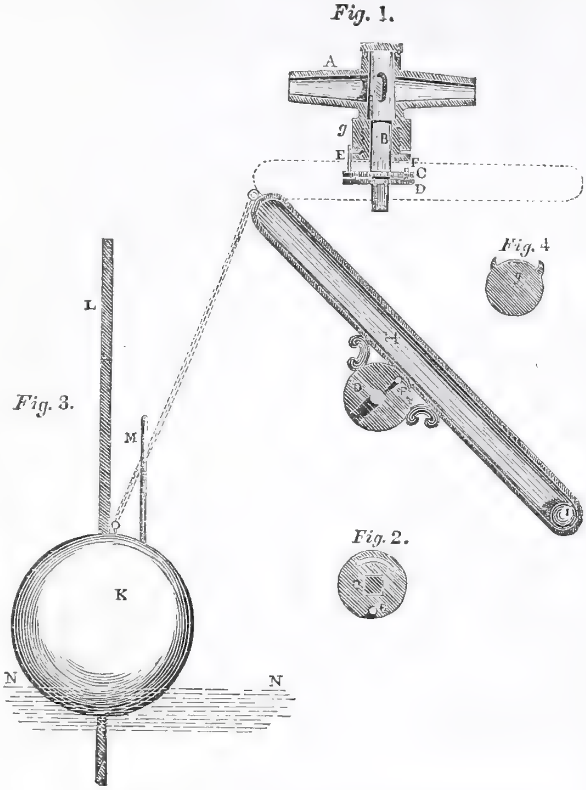
A, fig. 1, is a stuffing-cock; B is the key of the cock, having two flanches, C and D, on it, the one fixed, the other moveable. Fig. 2 is a view of the flanch, C, having a square hole in its centre, and an oblong hole in the face; this flanch is fixed tight in the spindle of the key, B. In fig. 3 is shown the flanch, D, having a round hole in its centre, and a pin, F, in the face. This flanch moves freely on the spindle of the key.

On the flanch, D, is fixed the tube, H, closed at both ends, and having a metal ball, I, moving freely inside of it. When the two flanches, C and D, are fixed in the spindle of the key, the pin which is in the flanch, D, works in the oblong hole of the flanch, C.

The cock acts thus:—When the cistern, N N, is filling, the hollow copper ball, K, fig. 3, will rise and lift the end of the tube, H, which being raised past the level, will cause the ball, I, within it, to move to the other end, and thus bring down the tube: the pin which is in the flanch, D, being brought round with the tube, will strike the end of the oblong hole in the flanch, C, which will turn the key, and thus shut the cock instantaneously.

When the cistern is emptying, the copper ball will descend, and, by means of the chain, will bring back the tube which is connected to it: the tube, when past the level, will cause the ball in it to return, and in this manner instantly open the cock.

Fig. 4 is a view of two studs that are fixed in the stuffing-box of



the cock; these prevent the tube from turning farther than is necessary to open or shut the cock, as the pin, E, which is screwed in the flanch in figs. 1 and 3, moves between these studs. M, fig. 3, is a small friction roller placed on the copper ball, K, which lifts the tube, H, more freely; F is a flat spear passing through the centre of the ball, for the purpose of guiding it.

BURLEIGH'S IMPROVEMENTS IN ARTIFICIAL LIGHT.

There are few subjects, in our dark climate, better adapted for receiving the attention of inventors than the production of artificial light. Mr. Burleigh, taking as his standard the light of the universe, the sun, has investigated its component colours, and the atmospheric action upon it, with a view to as close an assimilation as may be attempted. In the solar rays, three tints are so combined, that in their transmission through the azure atmosphere, they yield a perfectly colourless light. These rays are red, yellow, and blue, and it is to the just and exact balance of these colours that we owe our pure light. In artificial light, however produced, the equipoise is disturbed—the red and yellow tints predominate to a great extent over the third colour, the blue, and thus, all light so produced affects the natural and true colour of existing objects. To this reason we have to attribute the difficulty of discriminating between delicate tints when viewed by the light of a candle.

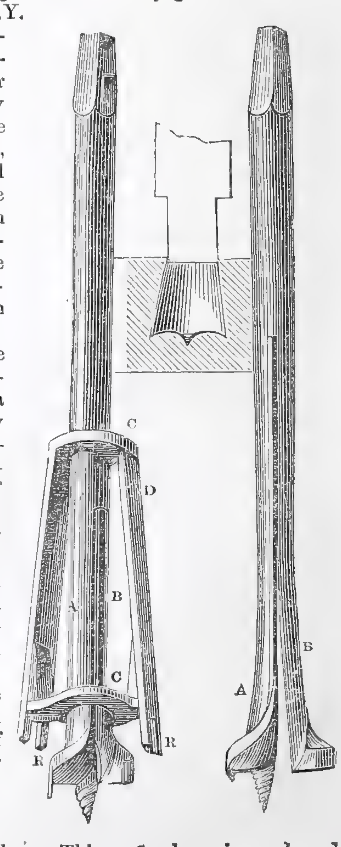
The object, then, at which Mr. Burleigh has aimed, is the reproduction of the correct mixture of the component rays. This he proposes to do, by transmitting the rays of artificial light through a glass medium, so prepared as to fulfil the important position held by the atmosphere in connection with solar light. When luminous rays are transmitted through tinted glass, it is known that those colours which are complementary to that of the glass, are in part neutralized, and the transmitted light is modified according to the colour of the medium employed. Experience tells us that the excess of colour in artificial light exists in the red and yellow tints; the corrective medium, then, must be blue, in order to cause the transmitted light to become achromatic. The depth of colour (which is to be obtained from cobalt) of the glass must depend materially on its form and thickness, and the nature of the uncorrected light; this point must rest for its complete elucidation upon the manufacturer's experience. The tests for arriving at the point of highest achromatic power, are furnished by Mr. Burleigh, as follows:—

"The corrected artificial light to be tested, being enclosed in a fitting box or lantern, let a direct ray fall on a white substance, as paper, side by side with a direct ray of a warm sunlight (as of a summer noon), in a room to which no other ray of light has access. So long as the ray of corrected artificial light is of a warmer or ruddier quality than the ray of solar light, the achromatic power is short of its highest intensity, and therefore within the range of true achromatic powers, or further and more perfect correction. If the artifical light appear colder or bluer, the medium is too deeply tinged, and is not an achromatic but a coloured medium, applicable in no way to the improvement of artificial light by the correction of the excess of coloured rays emanating therefrom. If the qualities of the respective rays be the same, then it will be evident that the highest point has been reached, and the medium is at its highest available power or state."

Although the purest artificial light thus obtained falls short of the excellence of the solar rays, yet it is evident that a considerable improvement must result from the application of Mr. Burleigh's theory. The glass, proposed by the patentee, differs in no respect, except in the achromatizing tint, from ordinary glass, and the medium may be in the form of a chimney, bulb, globe, or shade, as fancy or necessity may dictate. The colouring matter may either be applied to glass in its molten state, or it may be laid on its surface subsequent to its manufacture, always, however, adding the exact tint, which the exigencies of the case may demand.

IMPROVED EXPANSIBLE BIT.

The accompanying figures represent an improvement in expansible bits, for which a patent was lately granted to Clinton L. Adancourt, of Troy, N.Y.



The nature of this improvement consists in making expansible bits for boring conical holes any given distance into the material, and chip the core, so that it is discharged from the hole without the necessity of boring through the material, and so forming it that tenons may be firmly wedged into mortices, enclosing the tenon entirely.

Fig. 1 is a perspective view of the complete expansible bit; fig. 2 is a view of the bit itself fully expanded, without its collar; and fig. 3 is a sections, showing the form of conical hole made with the bit, and also the manner of wedging a tenon in it.

A bit or auger is formed in the usual manner, and then divided longitudinally into two unequal parts—the larger part, *a*, having the centre, and the other part, *b*, operating on a spring, at the point of which is the expanding cutter. The collar, *c c*, is then placed upon the shank, and presses the two sides of the bit together. This collar has wings, *d*, and projecting points, *r r*, extending down to the line of the cutting points of the bit. When the bit is brought into operation,

these points, *r r*, rest upon and are held firmly against the material to be bored; therefore, as the bit progresses or bores into the timber, the collar is pushed upwards, freeing the bit and allowing it to expand gradually, to form a conical hole, as shown in fig. 3, in which a tenon can be wedged neatly and permanently—impossible to be drawn apart or work loose. For very deep boring, an extra collar (forming a tube placed around *a b*, and embraced by *c c*) is employed, and the claim of the patent covers the expansible bit in combination with a single or double collar constructed and operating as described.

AGRICULTURE.

CHAPTER X.

FARM BOOKKEEPING.

The subject of bookkeeping is one that has, till within a very few years, been almost entirely neglected by farmers, although it is, undoubtedly, of the very greatest importance to them, and there does not seem to be any adequate reason that can be adduced for the neglect of it. What would we say of the merchant or manufacturer who carried on his business without keeping a regular set of books? We should certainly say that he was foolish in the extreme, and that it would most assuredly result in his affairs getting into a state of confusion, from which, in all probability, he would never be able to extricate them; and ere long he would find himself in a state of insolvency, without having even the poor satisfaction of being able to show his creditors how his funds had been expended, or by what means he had got into his present difficulties. And wherein does the case of the farmer differ from that of the manufacturer? Does not the seed represent the raw material? Is not the manure used by the one, an exact counterpart of the coal or other fuel used by the other? And are not horses, ploughs, and other implements, the machinery used by the farmer for the manufacture of the raw material into a marketable commodity? Then why, if there are so many points of resemblance between the farmer and manufacturer, should they differ in this, that the one can, and the other cannot, carry on his business without the use of account books? We think no one who considers the subject will deny that it is as necessary for the one as for the other, and we are glad to think that farmers themselves are now becoming alive to this fact, and that by far the greater number of them now keep books of some kind, although, generally, of a very imperfect description.

In our mercantile offices there are two varieties of bookkeeping practised, the one called bookkeeping by single, and the other by double entry. Now, although the latter of these is the one most approved of by merchants, it is not so well suited for farmers, as, from its complex nature, it requires more study than they can be expected to devote to it; and we will, consequently, confine our remarks to the first-named system, viz., bookkeeping by single entry. And after going over the books absolutely necessary, we shall notice some which, though not so positively essential, will yet be found very useful in showing the profit or loss on every variety of crop grown, and on every kind of stock kept.

The first book which comes under our notice is the memorandum-book, and we think we do not need to say anything regarding it, but that it is one which should be the farmer's constant companion, as in it he must note down every transaction at the time it occurs, for, more particularly in matters of money, the memory should never be trusted.

Having, then, got everything noted in the memorandum-book, there will be little difficulty found in keeping the next which we come to, the day-book, of which we give a specimen, by which it will be seen that everything sold from, and

Day-Book, March, 1850. 17

Folio in Ledger.				
	4th			
1	To Hay, W. Oliphant, 200 stone @ 6d.	£5	0	0
1	By Manure, From W. Oliphant, 2 tons 5 cwt. @ 5s.	0	11	3
	5th			
2	To Potatoes, A. Semple, 20 bolls @ 10s.	10	0	0
	6th			
Cash.	To Wheat, W. Mitchell, 12 qrs. @ 36s.	21	12	0
	To Barley, Disher & Co., 10 qrs. @ 28s.	14	0	0
3	By Manure, From Mitchell & Co., 2 tons guano @ £12 10	25	0	0
	7th			
4	To Potatoes, J. M'Arthur, 4 bolls @ 11s. 6d.	2	6	0

everything bought for the farm, is entered in it, to be thence carried to its proper place in the ledger; but before following the entries to it, we must notice the cash-book, which is the most important of all the series. On the left hand, or debtor (Dr.) side of this book, are entered all moneys received, and on the right hand, or credit (Cr.) side, all moneys paid.

11 Dr. Cash-Book. March, 1850. Cr. 11

March	1	To Balance in hand, ...	£27	12	6	March	6	By Commercial Bank, paid in, ..	£45	0	0
	6	" Disher & Co., for Barley, ...	14	0	0		9	" Labourers' Wages, see book, ..	1	11	0
	"	" W. Mitchell, for Wheat, ...	21	12	0		15	" Mitchell & Co., for Guano, ...	25	0	0
	9	" A. Semple, for Potatoes, ...	10	0	0		31	" Petty Expenses, ⅌ Petty Cash-book,	2	3	4
	15	" Commercial Bank, withdrawn, ..	25	0	0		"	" House " ⅌ House-book, ..	12	6	6
							"	" Balance to next month, ...	12	3	8
			98	4	6				98	4	6

As the transactions on a farm are not very numerous, it will be found sufficient to make up this book once a week, or even seldomer, as all the entries should be already in the memorandum-book, from which they have merely to be transferred to this. In the fourth entry, on the right-hand side (a number are of course supposed to have occurred between the third and fourth), we are referred to the petty cash-book; this is merely a subsidiary book, in which all small sums (such as tolls, market expenses, &c.) may be entered, to save a number of trifling entries in the cash-book, into which they are carried at the end of each month.

If the transactions of a farm were all cash ones, that is, if nothing was bought or sold without being paid for at the time, there would be no occasion for any more books, but as this is not the case, we require a record of outstanding debts, and this is afforded by the ledger.

In the first entry in the day-book, we find that W. Oliphant has purchased a quantity of hay, for which he has not paid. We have accordingly to open an account for him in the ledger, as we see in folio 1 of that book, where, on the left-hand side the hay is charged to him, referring for particulars to the day-book, folio 17; on the opposite side we place the manure received from him, also referring to the day-book; and on April 19th he has paid the balance, which would be found at folio 15 in the cash-book. In the same manner we open an account for A. Semple, on the second page of the ledger. The next two marked cash in the day-book do not require to appear in the ledger, as they have been sold in the market,

and paid for at the time. We next find accounts opened for J. M'Arthur, and Mitchell & Co., both taken from the day-book; and following these is the Commercial Bank account, the entries in which are brought from the cash-book; all sums paid into the bank being placed on the right hand, and those drawn out on the left-hand side of the ledger. It will also be found requisite to open accounts for each of the ploughmen; this would not be required if their wages were paid to them in one sum, but as they frequently get advances in the shape of coals, &c., it is necessary that they should appear in the ledger.

1850. Dr.		Folio in Day-book or Cash-book	Ledger.				1850.		Folio in Day-book or Cash-book.	Farm. Cr.			
1)			W. Oliphant.							Edinburgh.			(1
March	4	17	To Hay, ℘ Day-book, ..	£5	0	0	March	4	17	By Manure, ℘ Day-book, ..	£0	11	3
							April	19	15	,, Cash, ℘ Cash-book, ..	4	5	0
										,, Discount, ...	0	3	9
2)			A. Semple.							Gogar.			(2
March	5	17	To Potatoes, ℘ Day-book,	10	0	0	March	9	11	By Cash, ℘ Cash-book, ..	10	0	0
3)			Mitchell & Co.							Leith.			(3
March	15	11	To Cash, ℘ Cash-book, ..	25	0	0	March	6	17	By Guano, ℘ Day-book, ..	25	0	0
4)			J. M'Arthur.							Bridge-end.			(4
March	7	17	To Potatoes, ℘ Day-book,	2	6	0	May	25		By contra acct. for smith work,	5	7	6
June	7	24	To Cash, ℘ Cash-book, ..	3	0	0							
			,, Discount, ...	0	1	6							
5)			Commercial Bank.							Edinburgh.			(5
March	15	11	To Cash, ℘ Cash-book, ..	25	0	0	March	6	11	By Cash, ℘ Cash-book, ..	45	0	0

The only other book which we need mention is the field-workers' time and wages book. We give an example of the simplest form of it, and as it is generally kept by the foreman, the simpler it is the better. The first column, it will be observed, is devoted to the labourers' names, then we have a column for each day of the week, then one in which is entered the total time worked during the week, next one for the rate per day at which they are paid, and lastly, the amount of wages for the week. As we said before, this book is kept by the foreman, and all he has to do is to place opposite each labourer's name, who has worked a full day, the figure 1; or if, owing to wet weather or any other cause, they have ceased working at 12 o'clock, he will put down ½, to show that they have only worked half a day, or if they have not worked at all, he puts an 0 opposite their names. On Saturday afternoon the foreman hands in the book to his master, who calculates the wages, and either pays the people himself, or returns the book to his man, with the requisite sum to pay the wages.

Labourers' Wages Book.

March	4	5	6	7	8	9	Total Time.	Rate.	Wages.		
	M.	Tu	W.	Th.	Fr.	Sat.					
V. M'Queenie,......	1	1	½	0	1	1	4	1/4	£0	6	0
T. M'Gaughan,.....	1	1	½	0	1	1	4	..	0	6	0
P. Cramer, ...	1	1	1	1	1	1	6	8d.	0	4	0
Anne Mason, ...	1	1	½	0	1	1	4	10d.	0	3	9
Jane Scott, ...	1	1	½	0	1	1	..	..	0	3	9
Eliza Martin, ...	1	1	1	1	1	1	6	..	0	5	0
Jane Mowbray,.....	1	1	1	0	0	0	3	..	0	2	6
									1	11	0

Having now noticed all the books absolutely necessary, we shall proceed to describe one which will give the farmer a pretty correct idea of the profit he is making on each variety of crop and of stock. It may be called the crop and stock book, or by any other name that may be thought best. There have been many different forms of this book devised, but we shall only describe one which appears to possess considerable advantages. In it a double page is devoted to each field on the farm, headed with the name of such field, and the sort of crop under cultivation. On the left-hand side we enter all labour bestowed on the field, the manure and seed it receives, and its proportion of rent and taxes. On the right-hand side the field is credited with its produce at the date of thrashing each stack, and when all is thrashed, the difference between the two sides will, of course, show the profit or loss on the field. At the commencement of this book, it is useful to place a plan of the stack-yard, having a circle for each stack, containing the name of the field from which it was taken, and the sort of crop, and when it is thrashed, the date may be written below it. Besides having a page for each field, it will also be necessary to have one for cattle, another for sheep, and another for horses; the last of these is generally found the most difficult to keep with any degree of correctness, as it is not easy to ascertain the *exact* quantities of straw, hay, &c., given them, nor the quantity of manure with which to credit them, but a little experience soon enables the farmer to come pretty near the truth in both particulars.

We trust the system of bookkeeping which we have now described, is so simple that many farmers may be induced to commence keeping regular accounts, who have hitherto been deterred by a mistaken idea, that bookkeeping is only for those who have been trained to it from early youth in the counting-house of the merchant.

CHEMICAL MANUFACTURES.

CHAPTER III.

SULPHURIC ACID AND SODA.

We have seen, in the preceding chapter, that sulphur and salt are two of the abundant gifts of nature, which, by a few simple operations, man brings into a form practically serviceable to him in every-day life. Let us now see how, from these and a few other ingredients equally simple, some of the important chemical commodities are produced.

The "soda" or "white ash" of commerce is prepared from common salt, by decomposition with sulphuric acid, and igniting the so-formed sulphate of soda with coal-dust and lime; from this compound (black ash) the soda is dissolved by water, and the decanted solution being evaporated, furnishes the article in question.

We intend giving, in the following essay, the history and practice of the "alkali manufacture;" commencing with the preparation of sulphuric acid, and then proceeding to what may be more strictly called the preparation of the alkali. Though by no means pretending to make "every man his

own alkali manufacturer," yet we hope to be able to explain an interesting subject, not devoid of many novelties to the unprofessional reader, and to furnish to the professional one, a summary of facts connected with this important pursuit, which we trust may serve at least as a paper of reference suitable for consultation, conveyed in as plain language as the subject will admit.

THE PREPARATION OF SULPHURIC ACID, OR OIL OF VITRIOL.

This acid is composed of sulphur and oxygen; and the principle of the manufacture rests on the abstraction of oxygen from the atmosphere, under circumstances which enable it to combine with common sulphur; and all the arrangements of the sulphuric acid factories are conformable with this object. The greater part of the sulphur so employed comes from Sicily, because, unless commercial tariffs and restrictions interfere with its natural price, it can be obtained thence cheaper than from our own mineral districts; but if any circumstances should render the price of Sicilian sulphurs too high, means are adopted by our manufacturers for extracting sulphur from iron pyrites, a mineral extensively found in England.

About six years ago the price of Sicilian sulphur was driven up rapidly, through the following circumstance:—The sulphur mines in that country are the property of individuals; and from fifteen to twenty English firms, settled in Sicily, are engaged in the trade. In 1836, M. Taix laid before the Sicilian government a project for establishing a company which was to have the exclusive right, during ten years, of purchasing Sicilian sulphur at fixed prices on certain conditions. The British merchants becoming alarmed, the Sicilian government gave deceptive assurances, but persisted in their plan; and on July 4th, 1838, notice was given at Palermo that the monopoly would come into operation on the 1st of August ensuing. The negotiations respecting this monopoly were conducted with great secrecy; and it came into operation so suddenly that twenty-four vessels lost their cargoes. The British lessees of mines, and all others, were compelled to produce only a fixed quantity of sulphur; prices rose from £6. 10*s.* or £7 to £13 and £14 per ton, and contracts could not be completed. Previous to the monopoly, 484 British vessels sailed from the ports of Sicily to the United Kingdom; but in the first fifteen months after the monopoly the number was only 157. At length the British government took very decided steps to put an end to a monopoly established in the face of commercial treaties: the coasts of Sicily and Naples were blockaded by our ships of war, and the Sicilian government, no longer daring to uphold the monopoly, accepted the mediation of the King of the French in adjusting the dispute with the British government. After this, the trade resumed its former channel.

In many of the sulphuric acid works are ranges of upright furnaces, adapted for the extraction of sulphur from iron pyrites, in case such occurrences as these should again interfere with the sulphur trade. Into these furnaces is placed the pyrites, a mineral containing rather more than half its weight of sulphur, and rather less than half iron; and by a careful series of processes, a large per centage of the sulphur is obtained in a form fit for the manufacturer of sulphuric acid. But at the present time the price of Sicilian sulphur is sufficiently low to render the adoption of the English mineral unnecessary. This is one of the points to which we referred in illustration of the intimate connection between commercial legislation and chemical manufacture.

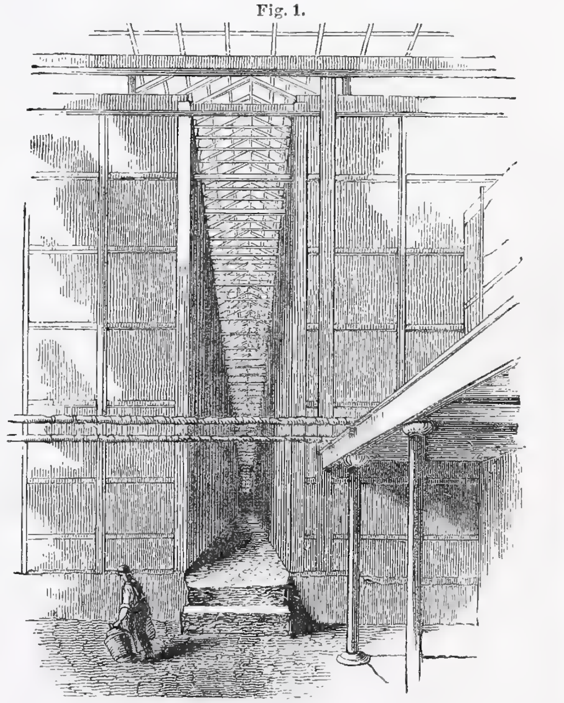
The Sicilian sulphur is brought over to this country "in bulk," that is, stowed away in the hold of the ship. It is prepared at the Sicilian sulphur-works in masses weighing about half a ton each; and these masses generally become broken into small rubble or fragments by the time they reach the English chemical works. So enormously has the use of this commodity increased in England, that whereas five thousand tons were used in 1820, ten times that quantity is now used annually; and we import, in fact, more than half of all the sulphur produced in Sicily.

We will suppose that a heap of sulphur lies in one of the warehouses of a large chemical work, ready to be operated on in the manufacture of sulphuric acid. In a furnace-room are numerous furnaces for burning the sulphur, arranged on each side of a hollow wall, through which the gaseous products ascend into large vessels. Every one knows that sulphur will kindle very readily, and it is equally well known that a very suffocating gas accompanies the blue flame resulting from the ignition. This gas is sulphurous acid, and the object of the manufacturer is to collect it carefully. The furnaces are a kind of flat quadrangular chest, measuring about seven feet by five; they are made of iron, and are capable of being closed in perfectly or nearly air-tight. There is a door in the front of each furnace, through which is introduced about a hundred pounds of sulphur at a time; the sulphur is kindled, the door is closed (leaving a narrow aperture for the entrance of the air required to support the combustion), and in about two or three hours the whole of the sulphur, except a very small residue or ash, is converted into sulphurous acid vapour, which ascends the hollow wall to fitting receptacles. If one of the doors be opened, we can see the lambent blue flame from the burning sulphur, and become sensible of the well-known odour resulting from the combustion.

The sulphurous acid gas passes from these burners or furnaces into vessels so vast, that it is difficult to estimate them by a common standard. Brewers' vats, 'Heidelberg tuns,' all sink into insignificance when compared with these vessels. In one particular factory there are two such vessels, each nearly two hundred feet in length, twenty in width, and twenty in height; and four others about half this length. They are not sunken tanks or cisterns, but vessels erected on the ground, formed of sheet-lead, and held together by appropriate framework. There are avenues between the vessels, or 'chambers,' as they are called; and nothing less than a walk from one end to the other of one of these avenues (such as is slightly sketched in the adjoining cut, fig. 1), can convey an adequate idea of the dimensions.

Into these chambers the gas passes; but not alone: there are some beautiful chemical changes involved before the

Fig. 1.



gaseous sulphur*ous* acid can be converted into liquid sulphur*ic* acid. The latter contains a little more oxygen than the former, for the same amount of sulphur; and a curious agency is employed for the supply of this additional portion.

Into the sulphur furnace is introduced a little nitrate of soda placed in a dish on a stand above the burning sulphur: the heat from the sulphur occasions the evolution of nitrous acid vapour from the contents of this dish; and this vapour enters the leaden chambers in company with the sulphurous acid vapour. The two gases will not exert any particular effect on each other while in this condition; but if moisture be present, an action immediately commences. There is a steam-boiler arranged near the chambers, from which a supply of steam is obtained; and this steam, flowing into the chambers with the two gases, effects a transference of oxygen from the one to the other. The sulphur*ous* acid only requires a little further supply of oxygen to transform it into sulphur*ic* acid; and this supply it obtains from the atmospheric air (which enters with it for the purpose) by the agency of the nitrous acid gas and the steam. Sulphuric acid is not a gas; it combines with the water of the steam, and accumulates at the bottom of the leaden chambers, from whence it is drawn off at stated intervals.

To explain the process more minutely, we may state that the sulphur*ic* acid is a compound of sulphur, oxygen, and water, containing, in its most concentrated form, 32·2 of sulphur and 56 of oxygen to 1 of hydrogen, and is produced in a humid atmosphere by oxidizing the sulphur*ous* acid (16·1 of sulphur to 12 of oxygen) formed by the combustion of sulphur, by the carrying or transmitting aid of certain peculiar compounds of nitrogen and oxygen. The changes by which sulphur*ous* is converted into sulphur*ic* acid are exceedingly interesting, and we owe to Sir Humphry Davy, MM. Clements and Desormes, the beautiful theory which we shall endeavour to illustrate. Sulphur*ous* contains only half as much oxygen as sulphur*ic* acid; nitre (nitrate of potash or soda) is a substance containing abundance of oxygen, which it readily parts with, though generally still combined with nitrogen. When sulphur is burned in dry air, or even in oxygen gas, sulphurous acid alone is produced; but as all substances are more powerfully disposed to form new combinations at the instant they are disengaged from pre-existing ones, it was judged that, by adding nitre to sulphur, and igniting the mixture, both sulphurous acid and oxygen (or rather a compound containing easily available oxygen) would be formed at the same instant, and, from the law before mentioned, would be disposed to unite and form sulphuric acid.* Putting this to the test of experiment, sulphuric acid was formed, and its presence was supposed to be sufficiently accounted for by this theory: but when Chemistry took its legitimate stand in the lists of practical science, and Lavoisier applied the balance to examine the product of experiments, the same cause that upset the favourite theory of phlogiston, overthrew that of the formation of sulphuric acid. It was found that the additional weight of oxygen added to the sulphurous acid exceeded, by many times, that of the nitre employed; and so reckoning that substance as consisting entirely of oxygen, and thus making the theory a present of the nitrogen and alkali, yet it had multiplied its weight over and over again. This, of course, led to a reconsideration of the subject, and the theory, slightly altered by various philosophers, at present stands thus:—The sulphurous acid, mixed with nitric acid from the nitre, watery vapour, and common air, becomes oxidized directly by the nitric acid, as in the theory of old; but the nitric acid does not part with all its oxygen, and it is this remaining compound of nitrogen and oxygen which plays the most important part in the process; the vessel in which the operation is conducted has an opening to the air, and the bottom is covered with water, into which the sulphuric acid condenses, by reason of its great affinity for that substance. The compound of nitrogen and oxygen remaining is termed nitr*ous* oxide, and possesses the property of uniting with more oxygen when presented to that gas, and then becomes peroxide of nitrogen. In the presence of atmospheric air it obtains the oxygen from that source; a mixture of dry sulphurous acid and peroxide of nitrogen remains without action, but if a small portion of steam be present, a crystalline compound is formed by the union of the two gases, and though a small portion of water is necessary for the formation and stability of this compound, yet a larger quantity decomposes it, giving rise to sulphuric and nitrous acids, the latter spontaneously decomposing into peroxide of nitrogen and nitrous oxide, which again seizes oxygen from the air, and transmits it to a fresh portion of sulphurous acid. The atmosphere thus becomes the source of oxygen by which the sulphurous is converted into sulphuric acid; and it is remarkable that the compounds of nitrogen and oxygen by which this is effected, are derived entirely from the nitre; the nitrogen of the atmosphere, being the most inert body in nature, is only brought into combination with other bodies with the greatest difficulty and by means of the most powerful agents, and fills no office in the production of this acid. If sulphurous acid, oxygen, and steam, were continually forced into a vessel containing a portion of nitrous oxide, the formation of sulphuric acid would proceed so long as the supply of these gases was continued; but the oxygen of the air being mixed with much nitrogen, the latter gas remains, and must be expelled to make room for the active gases; this unavoidably occasions the gradual waste of the nitrous oxide, for the whole of the gases being mixed together, a current out of the vessel must take some of all sorts with it; a constant supply of nitre is, consequently, necessary to supply the loss. Concentrated sulphuric acid absorbs or dissolves nitrous acid, and in some manufactories the air passing out of the "vitriol chambers," is conveyed over a very extended surface of the acid, obtained by filling a large cylinder with coke, and passing a current of acid through it. The gases thus absorbed are easily evolved when the acid is diluted, and the expense of concentrating the vitriol is substituted for the cost of the nitre. A patent has been obtained for this improvement, and it is found that the air still carries off a portion of the nitrous compounds, though a considerable saving is understood to result from the use of the contrivance. We subjoin a tabular statement of the formation of sulphuric acid, which will serve to fix the steps of the process in the mind:—

A mixture over water of	Sulphurous acid, Air, oxygen, and nitrogen, Steam,	gives	An aqueous solution of sulphuric acid. Air, with an excess of nitrogen. Nitrous oxide. Peroxide of nitrogen.

Sulphurous acid, steam, and air, being added to the residue, the nitrous oxygen appropriates oxygen, and sulphnric acid is again formed, and so the formation proceeds as long as the supply of the various gases is continued. The compound of sulphurous acid and peroxide of nitrogen must not be understood to exist only in theory, for its presence can be beautifully shown on a small scale by introducing sulphurous acid gas into a bottle slightly wetted with concentrated nitric acid, when the crystals will form a beautiful coating possessed of pretty considerable stability, but instantly decomposed by the addition of a little water, which retains the sulphuric acid in solution, and allows the nitrous acid to escape with effervescence. This experimental proof was devised by the late Dr. Dalton, though it was held by him to prove the formation of pure anhydrous sulphuric acid, but Sir H. Davy demonstrated that it could not be formed in the absence of water.

In Samuel Parkes' essay on sulphuric acid (Chemical Essays, 3rd edition, p. 212), are several very interesting circumstances connected with the history of this acid; to this source we are much indebted for the following account, as well as particularly the works of Brande, Thomson, &c.

Pliny in his Natural History mentions vitriol, but means by that term sulphate of iron, which may be called a natural salt, and still goes by the name of green vitriol, but it does not appear that he was in any way acquainted with its chemical composition. Raymond Lully, who was born at Majorca in 1235, said to have made gold in the Tower of

* The theorists, however, used the word 'phlogiston' where we have employed the term 'oxygen,' but the terms in this instance are in reality synonymous.

London in 1312-13, and said by some to have been stoned to death in Africa for preaching Christianity in the year 1315, and by others to have died in England in 1332 at the age of 97 years, was probably acquainted with this acid: but the first distinct mention of sulphuric acid occurs in the writings ascribed to Basil Valentine, a benedictine monk of Erfurt, Erford, or Enfort, in Saxony, said to have been born in the year 1394. Basil is esteemed one of the most celebrated alchemists, and has the creditable renown of introducing the use of antimony in medicine. In his "chariot of antimony," under the name of oil of antimony, he gives the following receipt for its production: "Take of antimony, sulphur, sal nitre, of each equal parts, fulminate them under a bell, as oil of sulphur *per campanam* is made, which way of preparing hath long been known to the ancients." He also describes in his Haliographia the mode of making green vitriol by dissolving iron filings in a mixture of one part oil of vitriol and two of water; and says, the salt obtained by crystallizing the solution is an excellent tonic, comfortable to weak stomachs, and when applied externally is a marvellous styptic. We need hardly say these medicinal qualities are quite correct, and have scarcely been improved upon since his day. The writings of Paracelsus, whose real name was Philip Hochener, but who styled himself Philiphus Aureolus Theophrastus Paracelsus Bombastus ab Hoenheim, or, when more modestly inclined, Theophrastus Bombastus Paracelsus, and who was born at Einsideln, near Zurich, in 1493, contain frequent allusion to oil of vitriol; but though chemistry and medicine are much indebted to the writings and life of this certainly talented man, few ever exceeded him in vanity and vice. The extent of his vanity and imprudence may be imagined from his speech to the University of Basle in Switzerland, upon his appointment in 1526, as the Professor of Physic and Surgery. He commenced by publicly burning the works of Galen and Avicenna, saying, his shoe-strings possessed more knowledge than they did, and as for himself, all the universities united had not as much knowledge as was contained in his own beard, and even the hairs upon his neck were better informed than all the writers that ever existed, put together. After leading a life of almost incredible activity, being an inveterate wanderer, and often associating, to use his own words, with chirurgeons, barbers, old women, gypsies, conjurors, and chemists, he died in great poverty at a mean alehouse at Strasbourg or Saltsbourg in Hungary in 1541, and in the forty-eighth year of his age.

It is also spoken of as a useful chemical agent by George Agricola, born 1494, at Glauca, in Saxony, and justly esteemed as the founder of the art of metallurgy; his celebrated work De Re Metallica, consists of twelve books, the first six treating of mining and smelting; the seventh—of "docimasy," or the art of ascertaining the quantity of metal that can be extracted from ores; the eighth—of the mechanical preparation of ores, and the mode of roasting them; the ninth describes smelting furnaces; the tenth treats of the separation of silver and gold by nitric acid and aqua regia, and gives minute directions for the preparation of these acids; the eleventh treats of the method of purifying silver from copper by means of lead, and the processes for smelting and purifying copper; and in the twelfth he describes the methods of preparing common salt, saltpetre, alum, and green vitriol—of the purification of sulphur, and the manufacture of glass; but the first really correct account of sulphuric acid was given by Gerard Dornæus, in a work he published in 1570, entitled Congeries Paracelsicæ Chemiæ de Transmutationibus Metallorum.

When sulphuric acid was first prepared, it was distilled from sulphate of iron, which is still known in commerce by the name of green vitriol or copperas; and as the chemical composition of neither acid nor salt was known, it was naturally enough called oil of vitriol; no doubt the oily appearance it presents when in a concentrated state, suggested or confirmed the name.

This mode is still followed at Bleyel in Bohemia, and at Nordhausen in Saxony, but has been abandoned in this country. Dr. Ward, the inventor of many celebrated nostrums, first introduced into England the mode of making sulphuric acid by burning a mixture of sulphur and nitre in glass globes set over water; the doctor was considered as the discoverer of this process, but this merit belongs to the French chemists of the 17th century, Lefevre and Lemery, and more particularly to the latter, Nicholas Lemery, who was born at Rouen on the 17th of November, 1645, and died on the 19th of June, 1715; he, however, observes, that he prefers the acid which is made without the addition of the nitre, though this addition is in fact the most important improvement in the manufacture.

In an old work, entitled "Polygraphices," published in England, most probably in the commencement of the seventeenth century, is the following formula for the preparation of "oyl of sulphur;" and as the mode described is that followed for the procuring "oleum sulphuris per campanam," or "oil of sulphur by the bell," previous to the introduction of Lemery's process by Ward, we shall give the extract at length:—

"OLEUM SULPHURIS, OR OYL OF SULPHUR."

"Take a little earthen cup, which turn upside down, upon which place another cup filled with melted sulphur; place these in the middle of a great earthen pan; over these hang a glass bell with a long neck like a matrass, an inch and a half in diameter, and about a yard long, having a hole at top to give vent to the air, which does advance the burning: give fire to the sulphur with a red-hot nail or some such like thing, and when your sulphur is spent, put new in the same place, and continue thus to do, until you have the quantity of oyl which you desire, which keep in a glass close stopt for use."

After giving these directions, the author points out the many marvellous medicinal virtues which were then ascribed to this "wonderfull oyl;" the healing powers of Parr's and Morison's pills are not greater, for "this miraculous oyl," says our author, "is an antidote against plague and all malign and pestilential feavers. It takes away coughs, colds, asthmas, &c. Cures the jaundice and hypochondriac melancholy, as well as consumptions, all ulcers of the lungs, dropsies and the gout!" Finally, it is to be obtained "of William Salmon, professor of physic, at his house, at the Blew Balcony, by the ditch-side, near Holborn Bridge, London, price eighteenpence an ounce." The price of concentrated sulphuric acid is now about three-halfpence per lb.

In manufacturing sulphuric acid, crude sulphur (from Sicily) is generally used, but iron pyrites (a natural compound of sulphur and iron) is in this country frequently employed as the source of sulphur. Since its first extensive use by Mr. Hill in 1818, at Deptford and Battersea, the formation of sulphurous acid is effected in appropriate furnaces, in which, by nicely regulating the size of the ore and the admission of air, the combustion proceeds without any other fuel than the stone itself. The iron of the pyrites becomes oxidized, and remains as a kind of cinder, of the same shape as the original lump of pyrites, which is broken, previous to burning, into pieces of about the size of a pigeon's egg; the smaller pieces are mixed with clay, and made into balls of the same size; for small pyrites will not burn, as the pieces lie too close together and prevent access of air. The nitric acid is evolved from a mixture of sulphuric acid and nitrate of soda (South American nitre), which is placed in an iron dish in close proximity to the burning pyrites, the necessary heat being obtained from that source; the sulphurous and nitric acids pass by the chimney of the same furnace into a large leaden chamber, which is also supplied with steam from an adjacent boiler; the floor of the "vitriol chamber" is covered with water to the depth of about 4 inches, and into this the sulphuric acid falls as fast as it is formed by the complicated reactions which we have endeavoured to explain; at a low temperature no sulphuric acid is formed, but a moderate degree of warmth (130° to 140° Fahr.) favours its production; the heat of the steam and of the gases from the furnace is generally sufficient for this purpose, though, when pyrites is employed, the quantities of the oxides of antimony and arsenic which are then sublimed, render it advantageous

to make the flue of considerable length, that these oxides may be deposited; but this of course reduces the temperature of the current, and sometimes renders it a matter of great difficulty to maintain the heat of the chamber. The knowledge of the influence of warmth and the introduction of steam have tended to advance the manufacture very considerably, and are the principal causes of the increased rapidity of production which characterizes the modern process.

The introduction of leaden chambers in place of the glass globes or bells, was the first important step after the use of nitre; the first chambers were erected by Dr. Roebuck and Mr. Samuel Garbett at Birmingham, about the year 1746, and were nearly six feet square; iron plates were placed a few inches above the water, and on these was burned the mixture of sulphur and nitre; the "charge" being "spent," about three hours was allowed for the gases to condense, and the chamber was then thrown open for a considerable time longer, in order to "sweeten" before the introduction of a fresh charge. From the works at Birmingham, the plan was distributed over various parts of the country by discharged servants; and the discovery, in 1788, of the mode of bleaching by chlorine, gave a considerable impetus to the trade, and assisted to raise it to its present importance.

Fig. 2.

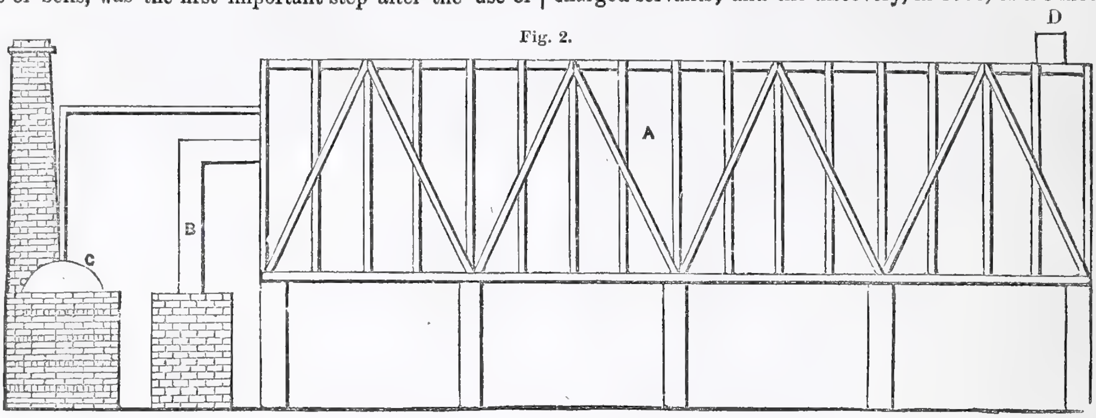
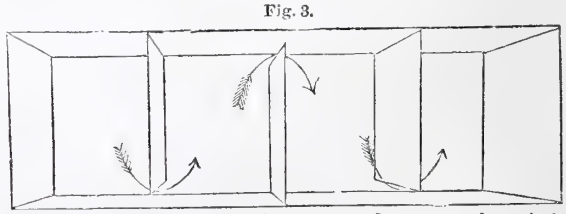


Fig. 2 of our accompanying illustrations will convey some idea of the general arrangement of the apparatus at present employed. A is the leaden or "vitriol chamber," the size of which varies very greatly according to circumstances, being from 20 to 120 feet long, and from 12 to 40 feet wide, and of proportional height. Lead of about 10 lb. to the foot is used for the bottom, and 4 or 5 lb. lead for the sides and top; and it is essential for the durability of the vessel that the sheet lead employed in its construction be made entirely from new metal, as when old lead is mixed with new, a considerable portion of tin is introduced in the solder (made of tin and lead), which is generally attached to old metal, and a very small portion of tin in the lead enables the acid to corrode it very speedily. The vitriol chamber is supported by a strong wooden framing, and rests upon brick or stone pillars about 7 or 8 feet high, so that the acid may be sufficiently elevated to flow in various directions without being pumped or carried; this arrangement also admits of easy access in case of repairs, and causes the chamber to act as a roof to the ground it covers, which may be easily converted into store-rooms, or used as sheds. B is the pyrites furnace, C the steam boiler, and D the outlet for uncondensed gases. As most of the acid is found at the end next the furnace, the bottom of the chamber is divided into compartments, so that the stronger acid may be drawn off, whilst the weaker portion is left for as much longer as may be necessary for its complete saturation. It is not found economical to carry the process in the vitriol chamber farther than sufficient to give the acid the specific gravity of about 1·35, for strong acid absorbs the heterogeneous compounds so frequently spoken of in the former part of this paper, and therefore the nearer the acid is to saturation the more difficult it becomes to increase its strength by this means; but when required of a greater density, it is concentrated or "boiled down" in leaden pans enclosed in brick-work over suitable grated rooms. The concentration cannot, however, be carried further in these vessels, when the acid reaches the specific gravity of 1·65 or 1·7, as when it is carried beyond this point it acts with great energy when heated in contact with lead. For still greater concentration, glass retorts were formerly employed, but evaporating pans of platinum enclosed in iron casings are now substituted; and though they cost from one to two thousand pounds each, and seldom last more than two years, yet the indestructibility of the metal, in comparison with the brittleness of glass, renders it economical to employ them.

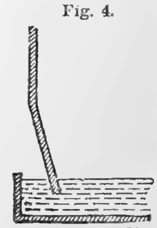
The use of solder for making the joints of the leaden vessels is now superseded by the autogenous system of effecting the junction of the plates, and with most complete success This process is performed by burning the plates together without solder, and may be briefly described as consisting in the employment of the intense and concentrated heat of an air-hydrogen blowpipe, the flame of which is directed to, and instantaneously melts a small spot on the edges of the leaden sheets, at the same instant that a drop of lead melted from a rod held in the flame falls upon the same spot; a solid junction of pure lead is thus formed, on which the acid exerts no more influence than on the general body of the sheet. The interior of the chamber is sometimes divided by leaden curtains or diaphragms open alternately at top and bottom, in order to insure the more effectual mixture of the gases. A view of this arrangement is given in fig. 3.

Fig. 3.



There are several ingenious appendages to the vitriol chamber, the most useful one being shown in fig. 4; it is, in fact, a portion of the side of the chamber pushed inwards; the edge, by dipping into the liquid, prevents the escape of gas, and the opening supplies the means of guaging the depth of the acid and obtaining a sample of the product. The state of affairs inside is generally judged of by the smell of the gas issuing from the vent, D: if too sulphurous, more nitre is added; if too nitrous, more sulphur, and so on. The strength of the acid is estimated by its specific gravity, and this is ascertained by the hydrometer. This instrument is doubtless well known to most of our readers, but there is a peculiarity about it upon which its correct indications entirely depend—this is not so universally understood.

Fig. 4.

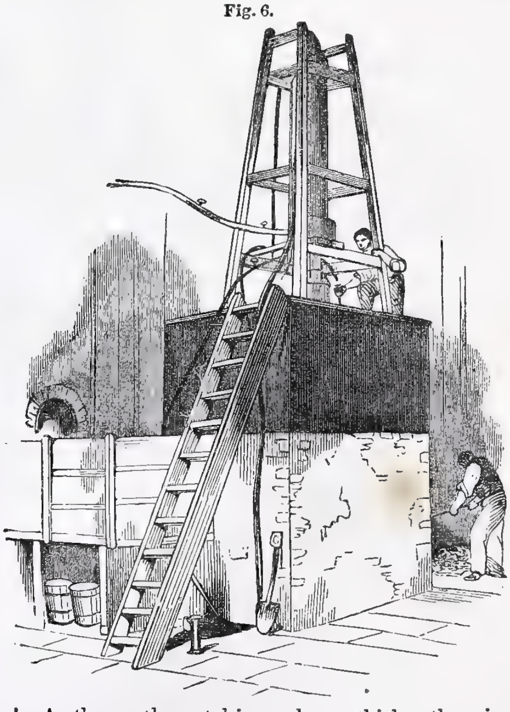


The hydrometer is essentially a parallel rod, graduated by divisions of equal value, and capable of floating perpendicularly when immersed in a liquid; its principle is, that it sinks much in light, and little in heavy liquids, the difference in density of the liquids being shown by the number of degrees at which the level of the tested liquid stands, so that the value of the degrees being known, the specific gravity of the liquid is immediately ascertained. These degrees, though equal in value, are not of the same dimensions at both ends of the scale; we shall point out the reason of this, and then show how any two points on the scale being obtained, the rest of the divisions may be easily and accurately ascertained by a simple mode, which we believe will be found to be highly useful to most manufacturers, whose avocations render the use of the instrument necessary. If we were to immerse a rod 20 inches long and 1 inch square, weighing 1000 grains, loaded so as to float vertically, in a liquid weighing 100 grains to the cubic inch, the rod would float 10 inches in the liquid and 10 inches out; the reason of this being, that the weight of the liquid displaced by a floating body is equal to the weight of that body, and because 10 inches of the liquid would weigh 1000 grains, and 10 inches of the rod would displace 10 inches of the liquid, therefore the rod would be balanced when immersed to that extent. Where the surface of the liquid cuts the rod, we make our first line, and will ascertain where the next two divisions (representing an addition of 10 grains to the inch of liquid) will fall; if the rod were immersed in a liquid weighing 110 grains to the cubic inch, from the reason adduced above $9\frac{1}{11}$ inches of immersion ($110 \times 9\frac{1}{11} = 1000$) would suffice to balance the instrument; this division would therefore be $\frac{10}{11}$ths of an inch long. If immersed in liquid of 120 grains to the cubic inch, $8\frac{1}{3}$ inches would displace 1000 grains ($120 \times 8\frac{1}{3} = 1000$), and this division would give $\frac{25}{33}$, or nearly $\frac{8}{11}$ths of an inch long. Again, if the liquid weighed 90 grains to the inch, $11\frac{1}{9}$ inches must be immersed ($90 \times 11\frac{1}{9} = 1000$), and this division would be $1\frac{1}{9}$ inches; and if in a liquid of 80 grains to the inch, $12\frac{1}{2}$ inches would sink ($80 \times 12\frac{1}{2} = 1000$), and this division would be $1\frac{7}{18}$ inches long. We have thus four degrees of the respective lengths of $\frac{25}{33}$, $\frac{10}{11}$, $1\frac{1}{9}$, and $1\frac{7}{18}$ inches long, each equal in value, *i. e.* each representing the addition of 10 grains in weight to each inch of the liquid, but varying considerably in length. It may easily be shown that these proportions are constant for the same liquids, irrespective of the size of the hydrometer, or the length of its degrees; for example, if the length of a division between the two liquids, 120 and 110 grains to the inch, was half an inch, we could calculate the rest by simple proportion, thus: as $\frac{25}{33} : \frac{10}{11} :: \frac{1}{2}$ for the next division, and as $\frac{25}{33} : 1\frac{1}{9} :: \frac{1}{2}$ for the next, and so on; but the calculation of these would be inconvenient and costly in practice. We have therefore given, in Plate VIII., a scale prepared with great care, and of the full size, for graduating hydrometers, not to the hypothetical specific gravities used above for the purpose of illustration, but to Twaddel's scale, in which every degree shows an increase of 5 ounces avoirdupois to the cubic foot of liquid, water being zero. If, therefore, we multiply degrees of Twaddel by 5, and add 1000 to the product, we shall have the weight in ounces of a cubical foot of the liquid under examination; and if we reckon three figures to the right as decimals, we have the specific gravity; thus, 125 degrees indicates that the liquid is 1625 ounces to the foot, and has a specific gravity of 1·625. The mode of using the scale is to obtain the two necessary points by immersing the hydrometer in two liquids of any known densities between the limits of the scale, and then, moving one of these points along the line belonging to that density (keeping the stem parallel to the transverse lines) until the other point coincides with the line belonging to that density, the intersection of the converging lines with the stem will show the other divisions. The hydrometer in general use in the chemical works is shown in fig. 5, and is made of glass, with an enclosed paper scale. These instruments are sold by glass-workers without scales, and with the end of the tubular stem open. To graduate them for use, the best plan is to place in the tube a piece of blank paper for the scale, about an inch shorter than the stem, and a small lump of shellac, sufficient to fasten the paper in its place, and to stop up the communication between the two balls; the instrument must then be immersed in a liquid of known density, and sufficient mercury poured into the tube to sink it to a convenient depth; the point of contact with the surface of the liquor is marked with a file, and another liquid of a different density being used, a second point is obtained in the same manner; the paper being withdrawn, the distance between the two marks on the stem is transferred to it, and the rest of the divisions are obtained from a scale similar to that given in the paper, and in a manner already described. A portion of the liquid is then melted at the neck of the two balls, to confine the mercury and diminish the risk of fracture; the remainder of the lac is melted on the upper end of the paper scroll, which is rolled up and reinserted in the stem, and the corresponding lines being brought to coincide with the file, when a little heat, applied externally, melts the lac and fastens the paper in its position; the scale is left shorter than the stem, while the latter is hermetically sealed before the blowpipe, which operation completes the instrument.

Fig. 5.

We have stated, that to give a high degree of concentration to the acid, the stills are made either of glass or platinum. When glass stills are used, they are heated by means of hot sand, into a bed of which they are placed; but breakages so frequently occur, that the use of platinum has almost superseded glass for this purpose. Platinum is a metal which will resist the action of nearly all acids; and as it will also bear a most intense heat, it is invaluable for such purposes as these. But it is procurable in such small quantities, and is brought into a marketable form with so much difficulty, that its commercial value is enormous. For concentrating the sulphuric acid at some of the works, platinum stills are used, which have cost several thousand guineas each, the value of the metal being several times as much as that of pure

Fig. 6.



silver! As the costly metal is made no thicker than is absolutely necessary, the portion of it exposed to the fire is protected by an iron casing.

It does not form part of our object here to describe manu-

factures in metal; but a few words may be introduced explanatory of the reasons why the production of platinum vessels is a difficult and tedious process. As the metal cannot be procured naturally in large masses, and as the heat of furnaces will not melt it, it is brought into workable form in an extraordinary manner, first developed by Dr. Wollaston. It is found in the metallic state in small grains, mingled with grains of many other metals. The other metals are removed from it by chemical means, and the platinum is then presented in the form of small grains. These grains are crushed in a wooden mortar with a wooden pestle to the state of powder, which powder is brought to a pasty form with water. The paste is put into a small ingot-mould, and pressed very powerfully by an appropiate machine, by which it is compacted into a solid form, the grains of powder cohering by a sort of welding property. This ingot is placed upon a charcoal fire, to drive away the remaining moisture; it is next exposed to the fiercest heat which furnaces can give, to remove every other extraneous substance from it; it is next hammered in particular directions, to give it a temper and toughness; and is then in the form of a small solid piece, fit to be rolled and forged into sheets, or any other practicable form. All this labour, bestowed upon a small bar only six or seven inches long, necessarily makes the manufactured article very costly.

After the acid has been concentrated to a density not much less than double that of water, it is cooled, and finally packed in large glass carboys enclosed in osier baskets.

The vitriol is seldom or never carried about the works in vessels, unless it is packed in carboys (large glass bottles) for sale, but is distributed through leaden pipes furnished with taps of the same metal, or of earthenware; in cases where the acid cannot flow over the works, a large cast-iron vessel, capable of being closed air-tight, and strong enough to withstand considerable internal pressure, is lined with lead, and placed in connection with the service pipes, so low that the sulphuric acid may flow easily into it: when full, the communications with the air and the source of supply are closed, and the liquid is discharged through the pipes by means of air forced into the vessel from a powerful pump. The quantity of oil of vitriol annually manufactured in the three kingdoms, is somewhere near sixty or seventy thousand tons.

As there do not appear, in common life, to be very many uses for sulphuric acid on a large scale, it may seem strange why such vast quantities should be made; since a large portion of all the sulphur imported is used in making this acid, and the acid produced is nearly three times as great in weight as the sulphur employed. But (as was before observed) it is as an agent in producing many other important chemical substances that this acid is so largely used; and to some of these attention may next be directed.

THE MACHINERY OF THE COTTON MANUFACTURE.

CHAPTER IV

The form of carding engine illustrated in last chapter is one of the ordinary kind, possessing no claims to novelty of arrangement or peculiarity of construction; but, nevertheless, affording to the uninitiated reader a very fair idea of the *modus operandi* of these machines.

Carding engines are of two kinds; one being that in which a series of "rollers" and "strippers" are used, as in the plate of "carding engine;" and the other in which "flats" are used, as in figs. 26, 27, page 215, Vol. III., at *e e*, *m m*. The "flat" system is by many preferred to the "stripper" and "roller," a greater carding surface being presented to the cylinder, and a better quality of work from inferior material produced. The wire, moreover, is presented in a more advantageous position for carding the cotton and opening the fibres. The great drawback, however, to the "flats" is, that they require constant attention; the flats being apt to become choked, if not frequently "stripped" and "set." In Leigh's patent self-stripping engine, the flats are not only made to strip, but to adjust themselves to the best angle at which they can operate on the cotton. A power of regulation of operation is also obtained, the flats being speeded as desired. In the plate of this carding engine, we give various drawings illustrative of the arrangement. The rollers in front of the "doffer" in fig. 1, are placed there in order to fill up the space which is left for the convenience of cleaning and "grinding" the cylinder. When "breaker" and "finisher" are used, these rollers are left out, the flats coming down to the doffer, this being made to lift up for that purpose, as shown in fig. 4 in the plate. The flats are raised with the greatest ease, being counterbalanced by the weight, L. The dotted lines in fig. 4, show the position in which the flats remain. To prevent the evil of chopping in the doffer rollers, a simple arrangement is made as at M; a roller covered with leather or other elastic substance being placed in front of the pair acting on the doffer. By using this, all the chopping, shaking, and vibration of the usual crank motion is obviated, and the fibres come off the doffer beautifully straight. The "peculiarity" of this engine can be applied to any existing form at a comparatively small cost. The following are instructions for using the patent engine:—Suppose you are carding 400 lbs. per week, and your engine is stripping one flat per minute, and you want to card 600 lbs., and of as good a quality, speed your doffer half as fast again as before, and the flats with it, and strip and grind your cylinder in proportion to the quantity carded, and your quality will be about the same. If, by that means, you have made more top strips, you will have made less fly, and your waste altogether will be no more in proportion to the cotton carded than before. If dirty cotton is used, the quality may be improved by speeding the flats alone. The top strips are of a better colour when taken off, than when done by hand. Where quantity alone is the object desiderated, the flats may be speeded to 10 or 12 per minute, stopping the "stripping comb," and allowing the "licker-in" to strip them as a clearer strips a roller. Where very heavy carding is required, a fancy roller, to keep the cylinder cleared, should be used; this may be applied either under the "licker-in," or be used in place of the rollers over the doffer. In starting new engines, care should be taken to see that the flats are ground up a little from the level or carding surface. This precaution being attended to, rectifies any little inaccuracy that may arise from negligent clothing or other causes; and curves them to the circle of the cylinder at the carding point, and brings more wire into action. This is done by making the bracket, H, press down the flats on the level surface. After the grinding roller, H, fig. 1, has been on a sufficient time to cause the flats to touch it uniformly, it must be taken off; taking care that always after this the bracket must act alternately on the straight and level part of the flat, when pressing them down for grinding. The grinding roller should be applied to touch the flats up about once in six months, and while the engine is at work. A very expeditious and accurate way of grinding the flats up at first, is to mount them on the top of an old carding cylinder, covered with emery in the same way as for carding, and lower them down gently as they slide over the flexible band; by this means a beautiful precision is attained, and superior work insured.

In fig. 1 in the plate, the roller "steps" slide in jaws radiating from the cylinder, and thus keeps the rollers exactly parallel with it; a point of great importance in good carding, and also a remedy against negligent setting. The distance between the rollers and clearer is adjusted by the size of the latter. To meet contingencies, unequal-sided steps are used, which, by being turned to one side or the other, accommodate different diameters of rollers.

In the plate, in fig. 1, H is the "grinding roller;" A, the "stripping comb;" B, the "traversing tops or flats." In fig. 2, part of the main cylinder is shown with traversing flats to larger scale. Fig. 3, *a a* is the flanch of fixed band; *b b* the flexible band over which the flats slide.

We now proceed to describe a few of the details of mechanism of the carding engine, and first, as to the "coiling of the sliver in the can." The great object to be effected in this depart-

ment, is the placing of the sliver in as compact a manner as possible. Were it allowed to fall in simply itself, and accommodate itself as best it could, a very slight quantity would evidently soon fill the can, and necessitate their frequent removal and loss of time. In the carding engine of Mr. Mason, of which we have given a plate, the coiling of the slivers is effected by the revolving can patented by Messrs. Tatham and Cheetham of Rochdale. The diagram in fig. 31 explains the operation of this. The sliver, after passing the delivery rollers, is passed down the tube, *a*, fig. 32, of the "pressing wheel," *b*, fig. 31; a horizontal circular motion being given to this, the sliver is consequently delivered in the can with a circular motion imparted to it. The pressing wheel, *b*, fig. 31, is placed eccentrically to the can, *a a*, which has a slow circular movement also. By the combined movements, the horizontal circular motion of the pressing wheel, *b*, the circular motion of the can, and the eccentric motion of the pressing wheel, the sliver is laid in the can in compressed coil, somewhat like the eccentric convolutions in an engine-turned watch "case." In fig. 32, which is a sectional elevation of the can, *a* is the delivery tube of the pressing wheel, *b b*, put in motion by the spur wheel, *c c*; *d d*, the can receiving motion by the wheel, *f f*.

Fig. 31.

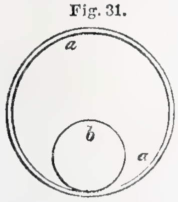
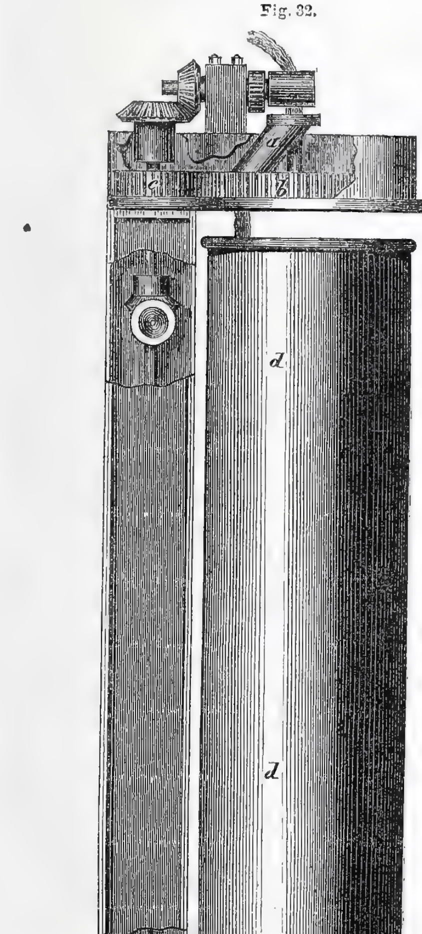


Fig. 32.



Another contrivance used for the delivery of the coil to the can, is that known as the "plunger," the invention of Mr. James Hill of Staleybridge. A sketch of this is given in fig. 33: *b* is part of the carding-engine gearing, giving motion to the wheel, *d d*; on the face of this wheel a stud, *e*, is placed eccentrically; a band, *f f*, passes over the pulleys, *g*, on the standard, *h h*; to the end of *f f*, a hollow metallic plunger is attached. This works up and down within the can, *m*, the plunger receiving an alternate motion by means of the band, *f*, and the eccentric stud, *e e*. The drawing in fig. 34 will show the arrangement as carried out in practice: *a a*, the doffer cylinder wheel of the carding engine; *b b*, the stripping comb and crank; *c c*, the can; *d*, the plunger; *e e*, the calender rollers delivering the sliver to the can. The inventor of this "plunger" has recently introduced another piece of mechanism for carrying out the coiling of the sliver of the can. A flat plate is placed above the can; this supports the bearers on which the calendering rollers revolve. These are placed so that the sliver is delivered to the can in the direction of the semi-diameter from the circumference to the centre, and from the centre to the circumference ultimately. In fig. 35, *a a* is the can; *b c*, the roller. When the sliver is passed from *c* to *b*, the sliver is laid from the centre to the circumference; and while from *b* to *c*, from the circumference to the centre. The sliver is made to slide from end to end of the roller alternately, by passing it through a mouth-piece, which has an alternate movement given to it by a cam. The variable rotatory movement of the can requisite is thus given:—The vertical driving

Fig. 33.

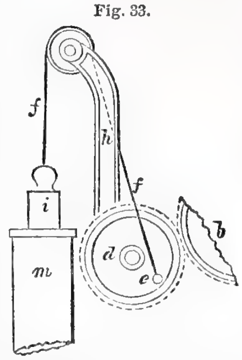
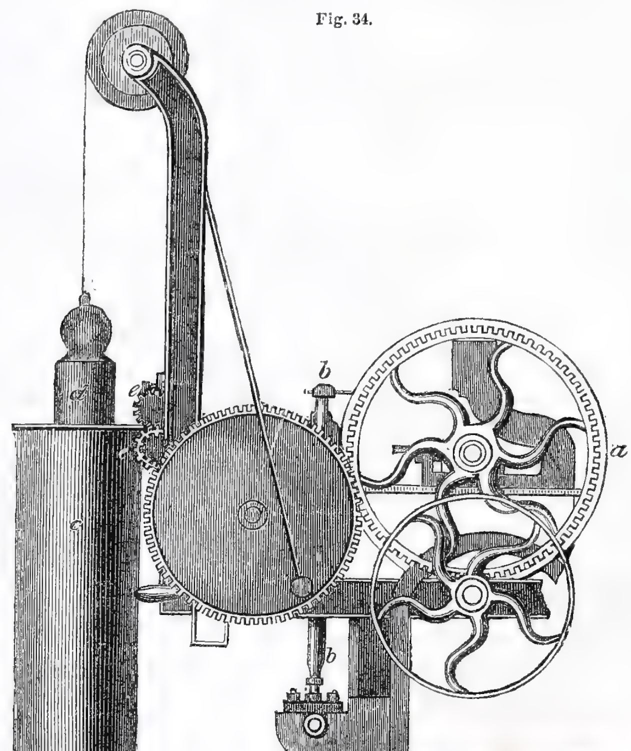


Fig. 34.



shaft which gives motion to the can for moving the guide piece which delivers the sliver to the roller, *b c*, fig. 35, is shown at *a*, fig. 36. A crank, *b*, fig. 36, is attached to the lower end of this shaft. The crank pin is attached to a small pin, *c*, which moves in a radial slot made in the toothed wheel, *d d*. The centre of motion of wheel, *d*, is eccentric to that of the shaft, *a*. In fig. 37, this arrangement is more plainly shown—*d d* being the horizontal toothed wheel; *a*, the vertical shaft; *c*, the crank, the pin of which moves in the radial slot in *d d*; *e* is the centre of motion of the wheel, *d d*. In fig. 37, the crank

Fig. 35.

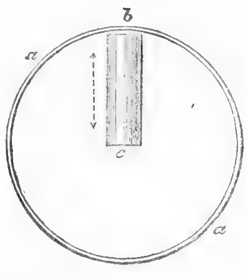
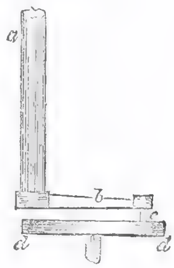
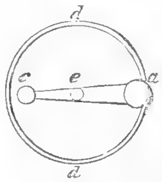


Fig. 36.



pin, *c*, is in the position at which it is nearest to the centre of the wheel, *d*; the crank driving the wheel, the latter will be moving at its slowest speed. When the crank pin is at its farthest distance from the centre of the wheel, *d*, this will be moving at its greatest speed. The variation of the speed of the wheel, *d*, which gives motion to the wheel in the plate supporting the can, is thus dependent on the degree of eccentricity the wheel has to the vertical shaft, *a*, fig. 36. As the can has thus the same variable movement as the wheel, *d*, the result of this arrangement is first to place the sliver loosely in the can, thereafter to compress it.

Fig. 37.



In fig. 38, we give a diagram illustrative of the method of coiling patented by Messrs. Lakin and Rhodes of Ardwick, Manchester. In the figure, *a a* are the delivery or calendering rollers through which the slivers are delivered to the trumpet-mouth girdle piece, *bb*. This vibrates or oscillates on a stud near the top, and a reciprocating motion is given to it by the connecting rod or lever, *d*, one end of which works in a centre at *c*, and on the other at a stud fixed in the face of the wheel, *e*, eccentric to its centre of motion. The sliver is laid in regular layers from *g* to *f* alternately, and as the can moves on a small railway in a direction parallel to the line of delivery rollers, the layers are placed side by side. Mr. Bodmer, the celebrated mechanician, formerly of Manchester, has patented a "feeder" adapted to "carding engines" and "beaters," which is possessed of considerable advantages. In fig. 39, we give a diagram illustrative of this. As the lap is taken from the roller, it is passed to the card roller, *b*, over the edge of the curved plate, *c*, from which it is taken by the "licker-in," *a a*. This arrangement enables the fibres to be laid much closer to the teeth of the licker-in than in ordinary circumstances. The fibres are taken hold of at both ends, and being held by cards and not by pressure, the "staple is not injured, but combed and pulled through the wire."

Fig. 38.

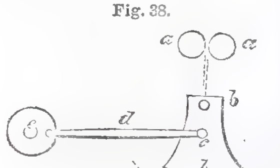
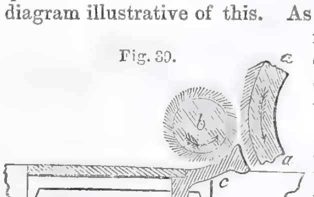


Fig. 39.



In next chapter we shall proceed to the description of the next process in the manufacture—"drawing."

ISOMETRICAL DRAWING.

CHAPTER I.

In chapter eighth of the "Illustrations of Mechanical Drawing," we have explained that, in the delineation of subjects, by the method of plan, elevation, and section, or by "parallel projection," as it is sometimes termed, each view of the same subject requires a specific and separate drawing. The most obvious advantage of this method of constructing drawings of mechanical or architectural subjects is, that *one* scale will serve for all the views, however numerous. But while useful, and very indispensable in a vast range of subjects, it is totally deficient in another important requisite—this is, the showing the relative position of horizontal and vertical planes, or the connection of lines which are drawn in a horizontal plane with those drawn in a vertical one. Thus, in the delineation of a plan, the whole details are confined to plan, no lines representing the parts in elevation being capable of delineation. Hence the introduction of methods of delineation, by which, in our drawing, the connection of horizontal and vertical planes could be plainly shown. If the reader will turn to page 392, vol. i., he will find in fig. 6 an exemplification of a method of showing, in one drawing, the representation of a subject of which three sides are given. Supposing this to represent the box, illustrated in figs. 1, 2, 3, chapter eighth, "Illustrations of Mechanical Drawing," it may be easily noticed how that the three views, each requiring a separate sketch, are all combined in one; the side elevation, end elevation, and the plan of top. (In fig. 6, p. 392, the top is intended to represent the slope of a roof, but for the purposes of our illustration we suppose it flat, or parallel to the bottom.) The method by which fig. 6, page 392, is delineated, is that known as "linear perspective." This species of delineation is not, however, applicable to practical purposes, in which measurements are required of the various parts of the subject, inasmuch as, from the principles of the style of delineation, the lines recede from one another, by which the effect of distance is produced, and thus different scales would be required for the different parts. To obviate this inconvenience, arising from the diminution of the lines of a subject, the various systems of "projection" have been introduced; by these, a cube, or any other figure, can be delineated without this diminution of parts, from the principle of supposing the objects to be viewed at an infinite distance, thus giving an equal size to all the parts, from each being looked upon as *equally distant* from the eye of the spectator. The methods of "projection" are exceedingly numerous: it is not, however, within the province of the present paper to give even a cursory detail of the principles of these; suffice it to state, that the species of projection, known as "isometrical," is the only one by which lines drawn in horizontal and vertical planes combined, can be measured from one scale. It is the purpose of the present paper to explain its principle, and the application of it to the delineation of various subjects of interest and value to the artisan and practical mechanic.

The term "isometrical" is compounded of two Greek words, signifying "equal measurements," and was given by Professor Farish of Cambridge, who first elucidated its practical usefulness to that species of projection by which the representation of a cube was obtained, the lines of which forming the boundaries of the sides were all equal.

A cube is a figure which has twelve boundary lines of equal length, each line forming the extremity of two sides or faces; it has eight corners or solid angles, each formed by the meeting of three faces; and it has six diagonal planes, or may be cut diagonally in six different ways.

"All the diagonal planes are right-angled parallelograms; they are equal to each other, and are the greatest plane sections of a cube.

"The diagonals of these parallelograms are the longest right lines that can be drawn within the cube. As there are two diagonals to each diagonal plane, and six diagonal planes,

ISOMETRICAL DRAWING.

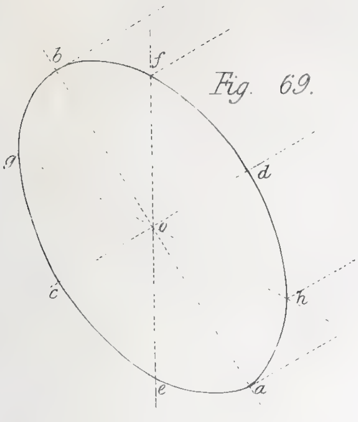


Fig. 69.

Fig. 70.

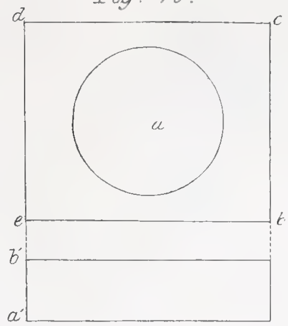


Fig. 71.

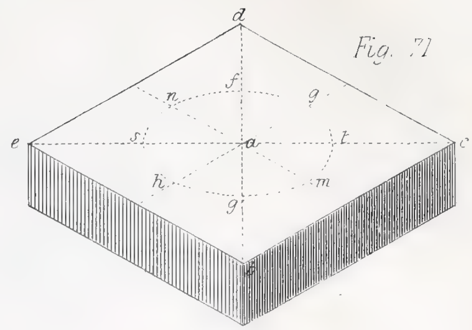


Fig. 72.

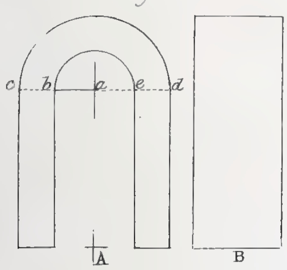


Fig. 73

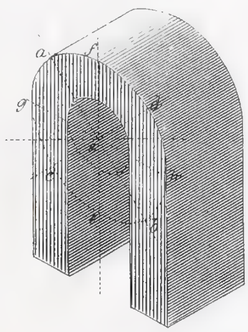


Fig. 74.

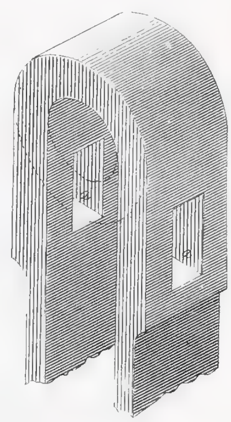


Fig. 75

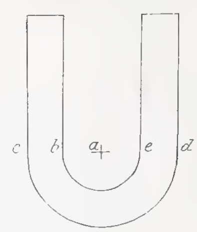


Fig. 76.

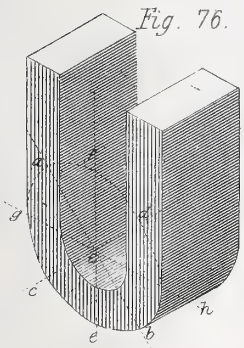


Fig. 77

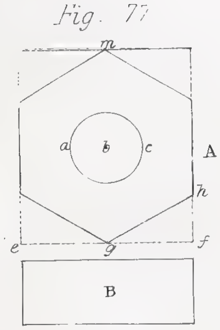


Fig. 78.

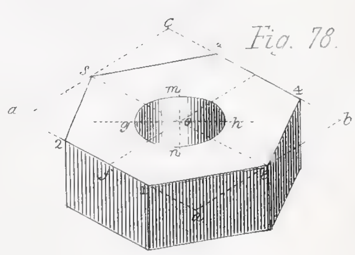


Fig. 79.

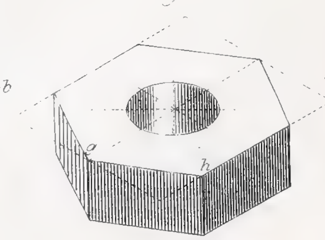


Fig. 80.

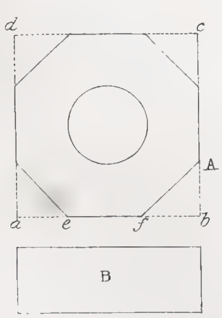


Fig. 81.

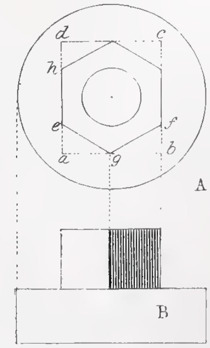
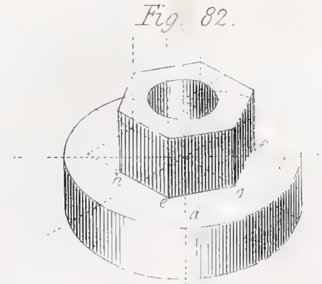


Fig. 82.



ISOMETRICAL DRAWING.

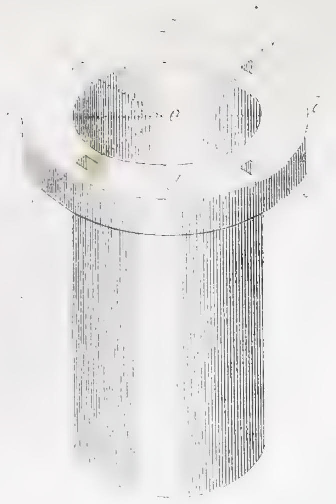


Fig. 84

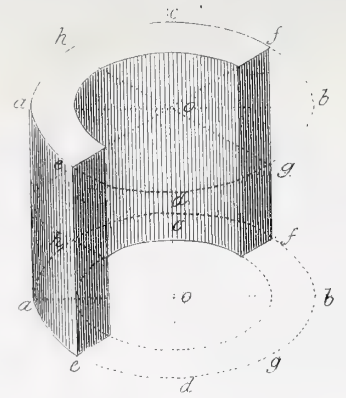


Fig. 85.

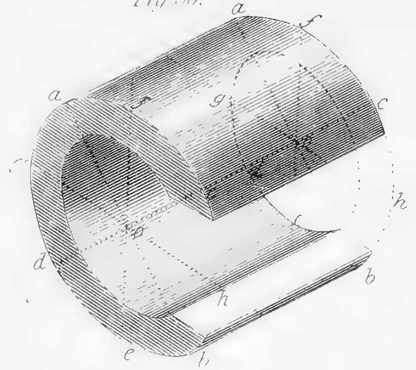


Fig. 86.

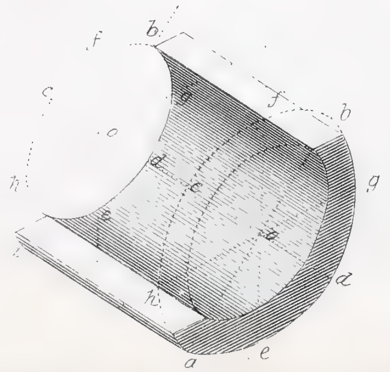


Fig. 87

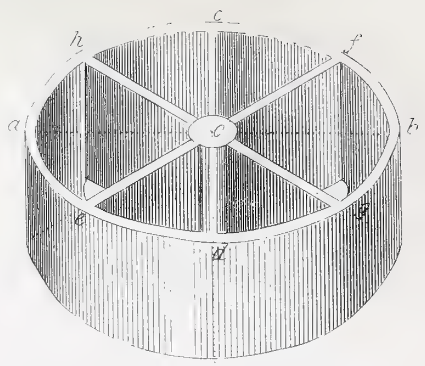


Fig. 88

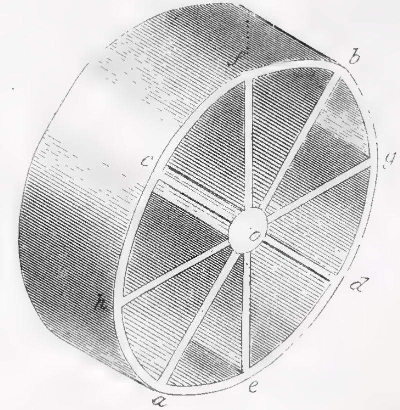


Fig. 89.

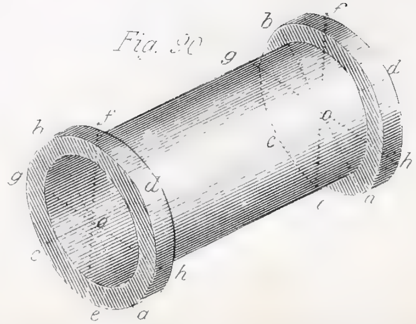


Fig. 90

Fig. 92.

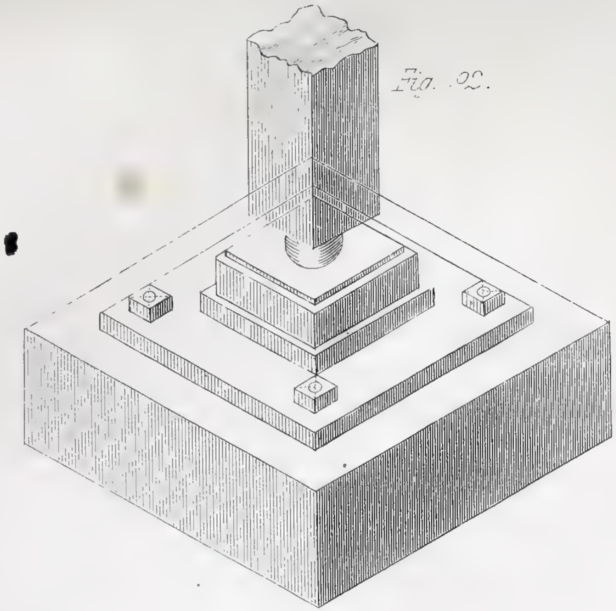


Fig. 93.

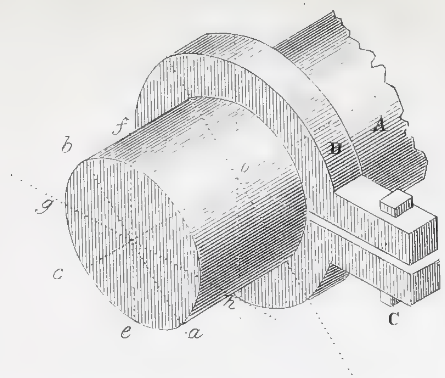


Fig. 95.

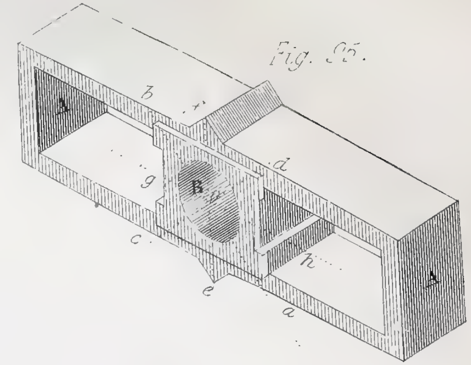


Fig. 96.

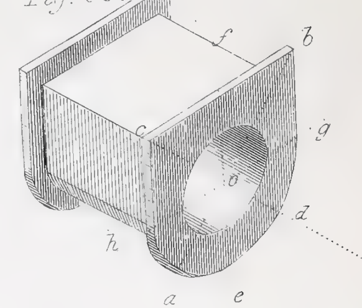


Fig. 94.

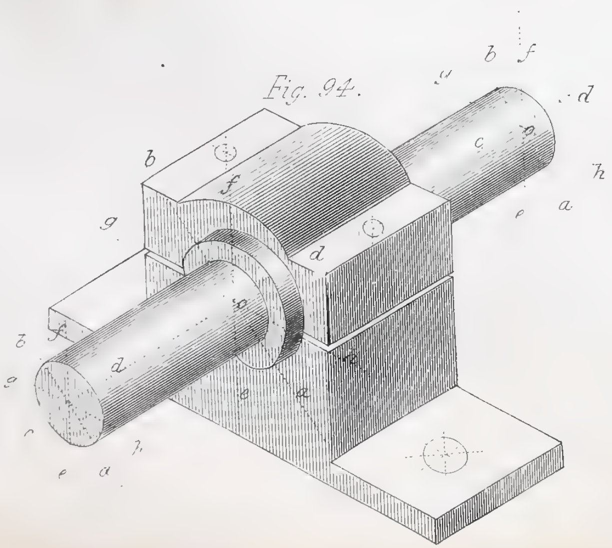


Fig. 97.

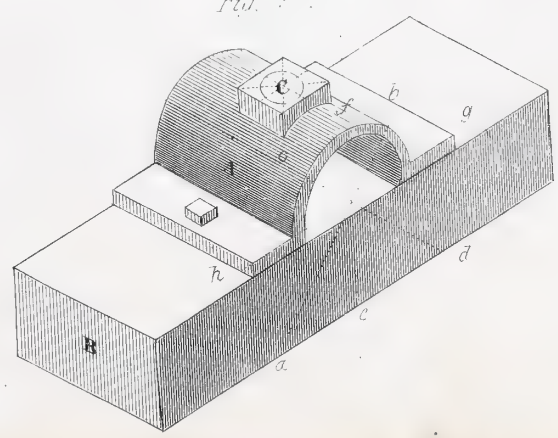
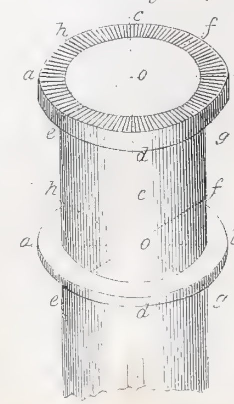


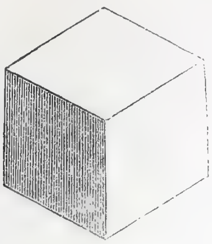
Fig. 91.



the cube would thus appear to have twelve diagonals; but in reality there are only four of these longest lines, the extremities of which are the eight corners, each line being a common diagonal to three diagonal planes.

"The section of a cube, cut by a plane parallel to any one of its faces, is a square equal to a face.

Fig. 1.



"Any other section of a cube, cut by any plane passing through four faces, will be either a square, a right or angled parallelogram, a rhombus, or a trapezoid.

"The section of a cube, cut by any plane passing through three of its faces, will be either an equilateral triangle, an isosceles triangle, or a scalene triangle.

"The section of a cube, cut by any plane passing through five of its faces, is a figure of five sides, but never a regular pentagon.

"The section of a cube, cut by any plane passing through six of its faces, will be a figure of six sides; when the plane divides two boundary lines on each face equally, the section will be a regular hexagon."*

In this system of drawing, the instruments necessary are the various kinds of compasses, a few set squares, or templates, cut to the angles of 30°, 60°, and 90°, as shown in fig. 3, with a parallel ruler, which can be used with advantage after a little practice; also, a number of isometrical ellipses of different sizes, with the major, minor, and isometrical diameters marked upon them, as hereafter described.

The method of constructing templates, as above alluded to, is given in fig. 14, chapter eighth, "Illustrations of Mechanical Drawing."†

To draw the representation of a cube, as in fig. 1.

Let the square, A B C D, fig. 2, be one face of a cube. Draw the two diagonals, A D and B C; make the angle, *a* B C, equal

Fig. 2.

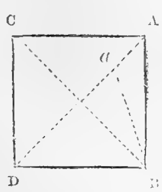
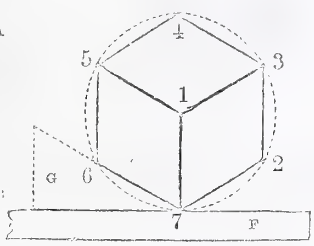


Fig. 3.



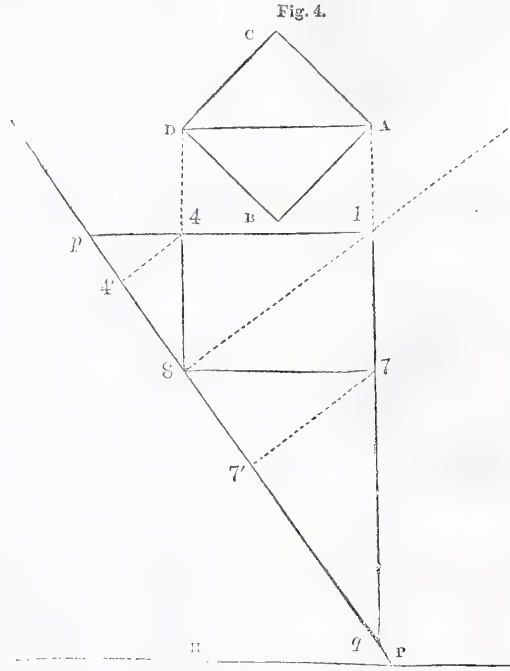
to 30°; then take *a* B as a radius, and with it describe the circle, fig. 3; with the same radius, which is equal to the side of an inscribed hexagon, divide the circumference of the circle into six equal parts, and draw three radii from the point, 1, to the points, 3, 5, and 7; then form the hexagon by joining the points, 2, 3, 4, 5, 6, and 7. Or, for general purposes, these lines may be more conveniently drawn by the aid of the simple instruments above mentioned. Thus, let F represent the blade of the drawing-square, and G the template, formed, as above stated, to set off the three angles, 30°, 60°, and 90°. By placing the square blade as shown in the figure, and applying successively the different edges of the template, G, to the edge of the blade, it is obvious that each of the angles at 1 may be marked off on the paper. In this operation the drawing-square may be placed either horizontally or vertically to the work.

"If fig. 2 represent the exact size of the face of any cube, then figs. 1 and 3 will, at a moderate distance, appear to be correct representations of a cube of that magnitude, of which they are exact projections. If each face of the cube be 100 feet square, then will A B, fig. 2, be a scale of 100 feet, by which the length of any line, or the distance between any points on or within the cube, may be ascertained; and by it the plans, elevations, and sections of any object may be drawn. By the same scale, also, the major diagonals, 3 5, 5 7, or 7 3, on the three faces of the representation of the cube in fig. 3, marked respectively A B C, may be measured."

Explanation of the representation of a cube, as projected in figs. 1 *and* 3.*

Let a cube, fig. 4, one face of which is the square, A B C D, be cut by a plane perpendicular to the surface, in the direc-

Fig. 4.



tion of the diagonal, A D; then the parallelogram, 1 4 7 8, will be its section, being a diagonal plane. On this section draw a diagonal from 1 to 8, and perpendicular to it draw P *p*, marking the direction of the plane, called the plane of projection, on which the representation of the cube is supposed to be made. Let the diagonal from 8 to 1 be indefinitely produced, and let the eye of the observer be placed in that line when viewing the point 1, which will therefore be projected upon the point 8; in like manner, when viewing the point 4, of which 4′ is the projection, let the eye be in a line with 4′ 4 produced; and again, when directed to the point 7, of which 7′ is the projection, let it be in a line with 7′ 7 produced. Now, by studying this simple diagram, in which are comprehended the principal elements of this system of drawing, the reader will find that, if the cube be placed horizontally, and the eye be brought to look upon it in the different positions above stated, the several points of the cube, when thrown forward on the plane of projection, will give, in the first place, the six points which form the hexagon, as shown in fig. 3; and then, by drawing the diagonals between these points, the cube will easily be represented complete, as in fig. 1, which is an exact projection, formed on the principles thus stated. The plane of projection to which we have alluded will, in that case, represent the paper on which the figure is to be drawn. When a thorough knowledge of the cube, and the diagonal lines which intersect it, is once acquired, little difficulty will be experienced in applying the same principles to any other object. For instance, the cube here represented may be supposed to be extended in dimensions to 100 feet or more, and this may represent the

* See Jopling's Isometrical Perspective, page 8.

† Mr. Sopwith's set of Isometrical Rulers, sold by Mr. Weale of Holborn, London, will be found useful; their accuracy may be relied on. Mr. Sopwith is the author of the admirable work on Isometrical Drawing, published by Weale.

* For this illustration we are indebted to Mr. Jopling's work.—See p. 11.

interior of a square building, in which is erected a steam-engine, manufacturing machinery, or any other objects whatever—all of which can be exhibited exactly in the same manner as the small cube in the diagram.

This will be elucidated by an inspection of fig. 5, the

Fig. 5.

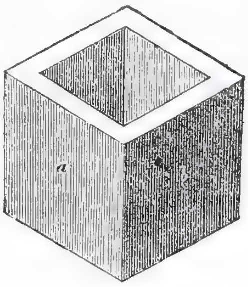
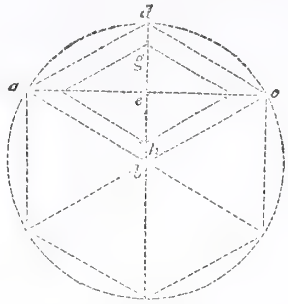


Fig 6.



method of drawing which, in the interior of a cube (described as explained in fig. 3), is illustrated by the diagram in fig. 6. The sides of the box, *a*, *b*, fig. 5, being the faces of the cube, of which *a b*, *b c*, are the upper boundary lines. The extent of opening is obtained by drawing a diagonal, *a c*, fig. 6, cutting *b d* in *e*, and from this point setting off to *g* and *h*; and from these points drawing lines parallel to the sides, *e a d*, *d e*, *c b*, *b a*; these lines being put in by the aid of the template, as in fig. 3. The object represented in fig. 7, is contained within the cube, shown by the dotted lines, fig. 8. The height of the various steps, as *a c*, *d e*, fig. 7, being set off from *a*, in the line *a b*, to *c d* and *e*. Lines from these points being drawn parallel to the side *a f*, or *b g*, and *g o*, the position of the point *n* is obtained by measuring from *e* to *n*; and from this point drawing a line parallel to *a b*. In like manner the methods of delineating the objects in figs. 9 and 10, are shown in figs. 11 and 12.

Fig. 7.

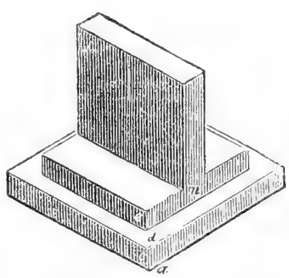
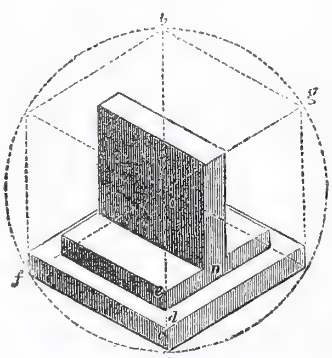


Fig. 8



As it is of the greatest importance that the learner should thoroughly understand the method of putting in the lines in various directions, coincident with the lines of a cube, described as in fig. 3; we here append four diagrams, from which he

Fig. 9.

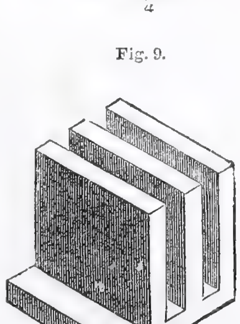


Fig. 10.

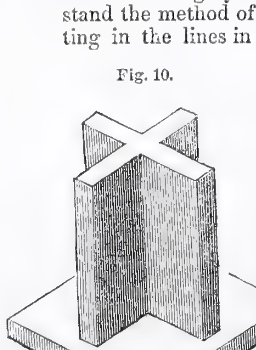


Fig. 11.

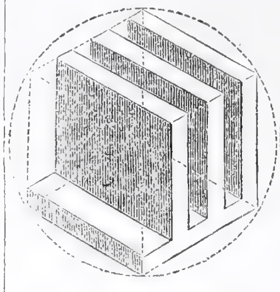


Fig. 12.

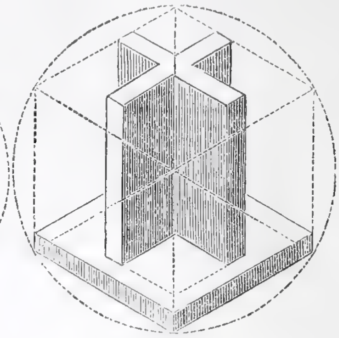


Fig. 13.

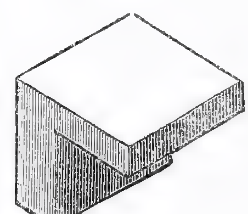


Fig. 14.

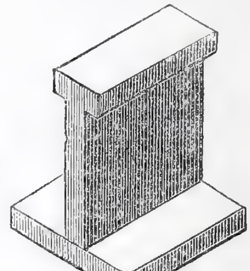


Fig. 15.

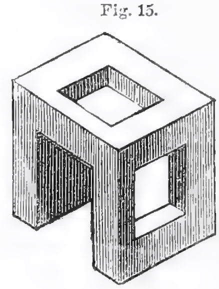
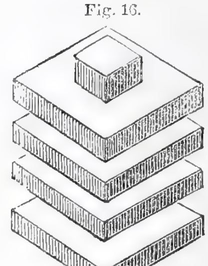


Fig. 16.



should construct four cubes, and draw the lines of delineation; the measurements of the various parts being obtained from the diagrams in figs. 13, 14, 15, and 16.

BOTANY.

CHAPTER XIII.

PHENOMENA OF DESCENDING SAP.

The fluid or gaseous matters obtained by the root from the soil, are either transmitted simply, or are formed into new combinations in the stem. When exposed to the atmospheric elements on its ascent to the leaf, the crude sap becomes highly charged with a denser nutriment; and Boussingault (Ann. des Scien. Nat. serié 2, xi. 31), from a careful series of experiments, in which he found a hydrogenated substance in plants, containing three times more hydrogen than is requisite to form water with the oxygen present, concluded that the water which remained after exhalation by the leaves was actually decomposed, and had its separated elements arranged into new combinations with the other plant constituents. The change which ensues is still more particularly manifested in course of the descent of the sap, during which it is distributed to the several organs concerned in the conservative and productive functions of the plant. The following experiment, allowing of being easily repeated, is recorded by Darwin (Phytol. sect. iv. 3), in illus-

Sexual Organs. *Nectarium resumed.*

Modes of Flowering.

Parts of Fructification.

tration of the point at which the ascent ends and the descent begins. "A stalk, with the leaves and seed vessels, of large spurge (Euphorbia helioscopia), in June, 1791, had been several days placed in a decoction of madder (Rubia tinctoria), so that the lower part of the stem and two of the inferior leaves were immersed in it. After having washed the immersed leaves in much clean water, I could readily discern the colour of the madder passing along the middle rib of each leaf. This red artery (?) was beautifully visible, both in the under and upper surface of the leaf; but on the upper side, many red branches were seen going from it to the extremities of the leaf, which, on the other side, were not visible except by looking through it against the light. On this under side, a system of branching vessels, carrying a pale milky fluid, was seen coming from the extremities of the leaf, and covering the whole under side of it, and joining into two large veins, one on each side of the red artery in the middle rib of the leaf, and along with it descending to the foot-stalk or petiole. On slitting one of these leaves with scissors, and having a common magnifying lens ready, the milky blood was seen oozing out of the returning vein on each side of the red artery in the middle rib, but none of the red fluid from the artery." Dr. Darwin adds: "All these appearances were more easily seen in a leaf of Picris, treated in the same manner, in which the colour of the madder seemed to pass further into the ramifications of their leaf arteries, and was there beautifully visible with the returning branches of milky veins on each side. In a plant which was sent me under the name of Senecio bicolor, the upper surface of the leaf is green, but during the vernal months the under surface is of a deep red, whence I conclude that the vegetable blood acquires the red colour in the terminations of the pulmonary artery in the upper surfaces of the leaves, which becomes visible as it passes in the large veins on the inferior surface." Agreeably to this last remark, the ascending sap is found in Euphorbia Canariensis to be bland and wholesome, while in its elaborated state, it is possessed of acrid properties.

In exogenous plants, the returning sap is usually considered to descend in channels through the liber or inner layer of bark, and through the alburnum or outer layer of wood. In Endogens, in like manner, the passage is through the parts which have been latest formed. The descent is thus accomplished in a somewhat circuitous manner, but in a way which must baffle the accuracy of immediate observation. We are, in fact, only permitted to see the ultimate deposition, it may be by degrees, of the alburnum and liber. These at first assume the form of a glutinous substance, to which the name Cambium is applied, consisting of the solid portion of the sap, when separated from the water that held it in solution. This becomes more and more consolidated, until the two layers are made integrant portions of the plant, the alburnum belonging to the wood, and the liber to the bark. That portion which flows along the liber, after nourishing the inner layer of the bark, descends to the root, which it serves to extend; and at the point where absorption had commenced, its redundant remains are excreted in the soil.

There is a form of circulation, however, characteristic, if it be not peculiar to the descent of the sap called Cyclosis, which differs from rotation or revolution within the bounds of the ordinary cellules, by being conducted in particular vessels possessed of proper membranes. The object of the first is to transmit the juices upwards; but the purpose of the second seems connected with the reduction of the sap to finished forms of composition. Another wide difference is, that while pressure suspends the movements of rotation in ordinary cases, it merely vibrates them in cyclosis. Green, who had inspected the vessels of the descending sap, gave them the name of *proper vessels;* but Professor Schultz of Berlin, after a more careful investigation, denominated the tissue of the vessels Cinenchyma (κινέω, to move), or laticiferous tissue; the fluid contained in it, the Latex; and the movement which takes place therein, Cyclosis (κύκλος, circle), in contradistinction to the true circulation of nutrient fluids in the higher orders of animals. The laborious results of Schultz were published in the year 1820, in a work intituled "Die Natur der lebendigen Pflanze."—(See Nova acta Acad. Cæsar. Leopol. Carol. Curios. tome xviii. Also Ann. des Sc. Nat. xxiii. 75.)

The Cinenchyma, or laticiferous tissue, is of a peculiarly ramifying form, yet uniting freely, so as to constitute a sort of network. The young stipules of the Fig, the bracts of Bird-weed (Calistegia sepium), and the petals of Poppy, present beautiful examples under the microscope.

Through this tissue passes the sap called latex, which appears to be a portion of the fluids belonging to the plant, separated from the rest, and undergoing its first organization. It is of a resinous nature, impregnated with oil and caoutchouc, and is viscid and insoluble in water. Its properties are sometimes bland, but often more or less acrid and poisonous. It is sometimes limpid, but more frequently of a closer consistence, and the minute globules with which it abounds form the occasion of its colour: white in Cow-tree, Spurge, Dandelion, and Lettuce; yellow in Celandine; red in Red-beet; and when brown or darker shades prevail, the opacity is owing to the globular structure of the granules.

The cyclosis itself is involved in much obscurity, All the circumstances essential to vital irritability in plants, as heat and light, are necessary conditions of its continuance; but none of these can be adduced as a true cause. The motion is best observed in lactiferous plants, as Convolvulus. The leaf sheath of the India-rubber Fig, when young and uninjured, is a good object for examination. The moving granules are regarded by Schultz as constituting the living part of the latex; but Mohl, backed by Tristan and Treviranus, contended that they are molecular movements, only going on when violence is offered to the vessels containing them. It is of paramount importance to distinguish between artificial movements of this nature, and frictional processes taking place within the interior of living vessels. Professor Balfour writes (Manual of Botany, 1849, p. 262): "From observations made last summer, I am disposed to agree with Schultz's statements. It is true, as Mohl remarks, that any injury done to the part examined, causes peculiar oscillatory movements, which speedily cease. Thus, if the young unexpanded sepal of the Celandine is removed from the plant and put under the microscope, or if the inner lining of the young stipule of Ficus elastica be treated in a similar manner, very obvious motion is seen in the granular contents of the vessels, and this motion is affected by pricking the vessels, or by pressure. In order to avoid fallacy, however, I applied a microscope to the stipules of Ficus elastica while still attached to the plant and uninjured, and I remarked, that while pressure with any blunt object on the stipule caused a marked oscillation in the vessels, showing their continuity, there could nevertheless be observed a regular movement from the apex towards the base, independent of external influences, when the stipule was simply allowed to lie on the field of the microscope without any pressure or injury whatever. This movement continued for at least twenty minutes during one of the experiments, and I have no doubt might have been observed longer."

The apparatus thus devoted to elaborate the sap, is associated with certain organs in which the secretion becomes located. In the lowest forms of plants, the simple cell is invested with the power of combining the elementary matter in a way suitable to itself; but the changes in that case, few and simple, become numerous and complicated as the scale of organization is ascended. When one cell is united with others, to form sets, endowed with a more extensive power of chemical action, the separate structure takes the name of gland, and though sometimes eluding observation in the higher orders of plants, it is either spread over the surface of a membrane, or collected into distinct masses. The alburnum and liber are no sooner begun, than they induce exterior changes, their cells absorbing the gummy substance of the sap, and converting it into starch or sugar or lignin. In the production of these plastic compounds the elementary substances are subjected to a great variety of arrangement, and the characteristic substance of each class constitutes what is called a *proximate organic principle.* Not the carbonaceous matter alone, but the earthy and metallic bases, and the saline compounds in the sap, are of powerful influence in determining and imparting special properties; and insensible portions of any one are capable, by a refined compli-

cation, of producing very wide results. Notwithstanding the difference, we say, of sensible properties among these bodies, their ingredients differ very slightly, and the chemical alterations required to complete them are strikingly simple. An analysis of volatile oils and resins shows an excess of hydrogen above the quantity required to form, in combination with oxygen, the element of water; in acid secretions, oxygen prevails; protein compounds, again, are characterized by nitrogen. The following analysis by Dr. Prout (Phil. Trans. 1827, p. 584,) exhibits the composition in a thousand parts of each substance:

	Oxygen and hydrogen united as in water.	Carbon.
Pure gum-arabic,.........	586	414
	Water.	
Dried starch,........	560	440
Pure crystallized sugar,...	572	428
Lignin from boxwood,....	500	500

Tromberg supplies the comparative value of certain articles of vegetable food, considered with a reference to their nutritive secretions, taking the values from a hundred downwards.

Beans,.....................	100	Rye,.........................	55
Pease,......................	80	Barley,........................	50
Oats,........................	75	Potatoes,....................	45
Wheat,......................	70	Rice,..........................	35
Maize,......................	60		

Any similarity which there may be among the secretions, appears to be arranged under similar organizations; and this uniformity characterizes the interminable catalogue of substances which may be extracted from the juices of different plants. "The oak, for example, forms, by the powers of vegetation, out of the simpler combinations of elementary bodies, not only the green pulpy matter of its leaves, and the light tissue of its pith, but also the densest of its woody fibres. It is from similar materials, again, that the olive prepares its oil, and the cocoa-nut its milk; and the very same elements in different states of combination, compose, in other instances, at one time, the luscious sugar of the cane, at another the narcotic juice of the poppy, or the acrid principle of the euphorbium; and the very same plant which furnishes, in one part, the bland farina of the potato, will produce in another the poisonous extract of the nightshade. Yet all these, and thousands of other vegetable products, differing widely in their sensible qualities, agree very nearly in their ultimated chemical analysis, and owe their peculiar properties chiefly to the order in which their elements are arranged; an order dependent on the processes to which they have been subjected in the system of each particular vegetable." Rodget's Veg. Phys. ii. 307, 308.

The general objects of secretion comprise both the formation and nourishment of the tissues. The substances to which it gives rise are either therefore retained in the vesicles where they were produced, or are merely stored up as magazines of nutriment to be used according to the requirements of the plant. The materials of food thus converted into a substance like that of the plant, and appropriated to the purposes of its increase or repair, constitutes the process of assimilation, that is, a process which extracts from the homogenous mass of nutritive fluid, whatever is required for the growth and conservation of its individual parts.

The vegetable secretions are exceedingly numerous, and compose nearly the whole of the solid parts of plants; so that the hardness and durability of wood, as well as its colour, smell, and properties, arise from matters secreted within the tissues. Some of these seem to be diffused universally, while others are limited both in quantity and distribution. The more general secretions may be exhibited by the maceration in water of any plant, for when all the soluble parts are removed by that means, woody fibre alone remains, and starch is deposited at the bottom. When the liquid is exposed to a boiling action, a scum is formed, and composed of albumen and other nitrogenous principles; and in the clear liquor, gum and sugar are present. The secretions that are of a special local nature, are either not generally diffused throughout the system of the plant, or take place in particular plants, as acids, alkaloids, resins, milks, and oils. The physiological, commercial, and medical importance of these secretions, warrants a connected though summary notice, but must be reserved for another chapter.

COMPENDIUM OF LOGIC.

CHAPTER VII.

PART III. CONTINUED—COMPOUND SYLLOGISMS—PART IV. FALLACIES OR SOPHISMS—1. LOGICAL FALLACIES.

In discussing the subject of Propositions, we showed that they admitted of division into Simple (or Categorical) and Compound (or *Conditional, Disjunctive*, &c.) These varieties of the Proposition necessarily lead to a similar division of the Syllogism, which may be either Simple or Compound, Categorical or Hypothetical, &c., according to the kind of propositions of which it consists. We have hitherto treated only of pure Categorical Syllogisms, falling, either directly or by an easy reduction to the first figure, under the general principle laid down in the Dictum. But reasoning is rarely confined to arguments cast in this simple form, though all may be reduced to it ultimately. Therefore we shall now proceed to consider some of the principal varieties under the general name of

COMPOUND SYLLOGISMS.

These may be divided into Hypothetical or Conditional, and Disjunctive syllogisms, the Dilemma, the Relative syllogism, Epichirema, Sorites, Prosyllogism, &c.

I. *Hypothetical or Conditional Syllogisms.*—The word *hypothetical* is sometimes used as a general term for both Conditionals and Disjunctives. Here we shall use it in the sense of *Conditional* only, which seems to be its more legitimate meaning, and in this sense, applied to a *proposition*, it signifies one which consists of *two categoricals* united by the conjunction *if*, or some equivalent conditional expression, as "The crops will be abundant, *if* the season is good." Now, in hypothetical (or conditional) *syllogisms*, such a proposition as the foregoing constitutes the *major* premiss, and that part which forms the *condition* is generally put first, thus:—

> If the season is good, the crops will be abundant;
> But the season is good;
> Therefore, the crops will be abundant.

It must be observed, however, that the mere fact of the major premiss of a syllogism being hypothetical in form, does not necessarily render the syllogism hypothetical. Syllogisms may be categorical even with *both* their premisses conditional; thus, in the following example:—

> If ignorance is not bliss, it is not folly to be wise;
> If the Esquimaux are wretched, ignorance is not bliss;
> If the Esquimaux are wretched, it is not folly to be wise.

Here we have a purely categorical syllogism, even though all the three propositions of which it consists are hypothetical. The reason is, that if the condition or contingency be carried forward into the conclusion and reappear there, the hypothesis is really a part of one or more of the terms, and clings to the syllogism throughout. The force of the reasoning in this case does not *turn* on the single hypothesis, "If ignorance is not bliss, it is not folly to be wise;" for this again turns on another hypothesis, "If the Esquimaux are wretched," which is retained as the minor term of the conclusion, and renders the conclusion itself hypothetical.

A hypothetical syllogism, on the contrary, turns entirely on one conditional proposition, forming the major premiss, which, being either affirmed or denied in the minor, renders the conclusion categorical: hypothetical syllogisms, therefore, yield categorical conclusions; as,

> If the army is well commanded, it will conquer;
> But the army is well commanded;
> Therefore, it will conquer.

Here the conclusion is a categorical affirmative, Let it be observed, however, that to draw a negative conclusion in this

case, it would not be sufficient to deny the *antecedent* of the major premiss:—

But the army is *not* well commanded;
Therefore, it will *not* conquer.

This conclusion does not follow; for though it is affirmed in the major that the army will conquer *if* well commanded, nothing is said to imply that if *not* well commanded, it will *not* conquer. In fact, the *consequent* "it will conquer" corresponds to the *undistributed* predicate of an affirmative categorical proposition:—

The case of the army being well commanded, is a case in which the army will conquer;

[—Not necessarily the *only* case. The rest of the syllogism then takes the following form]:—

But the present is a case of the army being well commanded;
Therefore, the present is a case in which it will conquer.

This, as the reader will perceive, is exactly a syllogism in *Barbara;* but let it resume its hypothetical form, and then we shall see that a negative conclusion can only be inferred by denying the *consequent*:—

$\underbrace{\text{If the army is well commanded,}}_{\text{Antecedent.}}$ $\underbrace{\text{it will conquer,}}_{\text{Consequent.}}$
But it will *not* conquer;
Therefore, it is *not* well commanded.

This conclusion is perfectly legitimate. Hence we find that in conditional syllogisms, that which corresponds to an affirmative conclusion is gained by admitting the *antecedent*, that which corresponds to a negative by denying the *consequent*, of the hypothetical premiss.

The reason or *rationale* of this is obvious. A conditional proposition implies, in its very terms, that if the antecedent is true, the consequent is true—if A is B, C is D; but it does not follow that if C is D, A is B. "*If I move my finger, the air moves,*" may, and must, be a true proposition; but it does not follow that, "*if the air moves, I move my finger,*" for the air may be put in motion by some other cause. The truth of the consequent, therefore, follows from the truth of the antecedent (by the terms of the proposition), but not the truth of the antecedent from the truth of the consequent; neither does the falsity of the consequent follow from the falsity of the antecedent, for C may be D, whether A is or is not B—it does not follow that the air does *not* move, if I do *not* move my finger. On the other hand, the falsity of the consequent implies the falsity of the antecedent, for if the antecedent *were* true, the consequent *would be* true also; therefore, if the consequent is *not* true, the antecedent must be false.

This reasoning holds good, whatever be the quantity or quality of either of the two members of which the hypothetical proposition consists; for all hypotheticals may be regarded as universal-affirmative, even though one or both of the two constituent propositions be either particular or negative. The proposition really consists in the *affirmation*, that if the antecedent is true, the consequent is true, and this *affirmation* is made *universally*—that is to say, the proposition is *universal-affirmative*, even in such cases as this:—

["If no A is B, some C is not D." For this is a mere *affirmative-universal*, that the truth of the consequent ("some C is not D") depends on the truth of the antecedent ("no A is B").]

When the consequent, however, is negative, that which is really an affirmative conclusion, as regards the truth of both members of the hypothesis, will have a negative form, and *vice versâ*. We therefore defined the conclusion which is gained by admitting the antecedent, as that which *corresponds* to an affirmative—that which is obtained by denying the consequent, as *corresponding* to a negative. The former may be actually negative in form, the latter affirmative. Thus, in the following example:—

If A is not B, C is not D,
But A is not B;
Therefore, C is not D.

This conclusion is negative in form, although it is by obtained *affirming* the truth of the antecedent, and therefore results in affirming the truth of the consequent. Again—

If A is not B, C is not D;
But C is D;
Therefore, A is B.

Here the conclusion, though affirmative in form, is really a *negation* of the truth of the antecedent, obtained by *denying* the truth of the consequent.

As the words *Affirmative* and *Negative* would therefore be ambiguous in this case, the terms *Constructive* and *Destructive* are used in their stead.

A *Constructive* Conditional syllogism is one in which, from admitting the truth of the *antecedent*, the truth of the consequent is inferred. In this case, therefore, an affirmative consequent will give an affirmative conclusion; a negative consequent, a negative conclusion.

A *Destructive* Conditional syllogism is one in which, from denying the truth of the *consequent*, the *contradictory* of the antecedent is inferred. In this case, therefore, an affirmative antecedent will give a negative conclusion, and *vice versâ*.

"If the barometer falls, it indicates rain or wind; but the mercury does fall, therefore it indicates rain or wind," is constructive. "If the storm continued, the expedition would not sail; but the storm continued, therefore the expedition did not sail," is likewise constructive, though the conclusion is negative.

"If it is to be fine weather, the mercury in the barometer rises; but the mercury does *not* rise, therefore it is *not* to be fine weather," is destructive. "If the wind did not fall, the expedition would not sail; but the expedition sailed, therefore the wind must have fallen," is also destructive, though the conclusion is affirmative.

In conditionals, we have seen that nothing can be proved by denying the antecedent or affirming the consequent. The assertion of the consequent, and thence inferring the truth of the antecedent, corresponds to the fallacy of undistributed middle term, or to that of two negative premisses; the fallacy of denying the antecedent, and thence inferring the contradictory of the consequent, either to negative premisses, illicit process of the major, or introduction of more than three terms.

II. *Disjunctive Syllogisms.*—These are syllogisms having for the major premiss a disjunctive proposition, on which the force of reasoning turns. A disjunctive proposition is one that consists of *two or more* categoricals, connected by the disjunctive conjunctions *either* and *or;* as, "Either A is B, or C is D, or E is F;" "Either testimony is false, or miracles were truly performed." Such propositions imply that one of the alternatives is true; and generally, though not always (where there are more than two alternatives), that each of the others is false. Thus, in the first example, if A is denied to be B, and C denied to be D, it follows that E must be F; and if A is admitted to be B, the proposition generally (though not uniformly) implies that neither C is D, nor E is F. Hence, a disjunctive *syllogism* takes the following form:—

Either A is B, or C is D, or E is F;
But A is not B, and C is not D;
Therefore E is F.

Or sometimes thus—

But A is B;
Therefore, C is not D, and E is not F;

though the latter conclusion does not always follow when such alternatives are stated. Thus, it may be true that "in winter, it will either rain or snow;" but if we admit that "it will rain," it does not necessarily follow that "it will not snow."

And here it may be proper to remark, that, as in the case of conditionals, so with disjunctives—the mere fact of a disjunctive proposition forming the major premiss of a syllogism, does not constitute that syllogism disjunctive, *e. g.*:—

A false prophet is either an enthusiast or impostor;
Mahomet was a false prophet;
Therefore, he was either an enthusiast or impostor,

is not a disjunctive, but a categorical syllogism; for it will

be seen that, in this case, "either an enthusiast or impostor" constitutes one of the terms, and reappears in the conclusion as the major. The force of the reasoning does not turn on the disjunctive, as it would do if one of its members were either affirmed or denied in the minor premiss; thus,

> But Mahomet was not an enthusiast;
> Therefore, he was an impostor;

which would make the syllogism disjunctive.

The analogy between Conditionals and Disjunctives does not end here. The latter, like the former, are always *affirmative;* that is to say, a certain connection is *affirmed* to exist between the two members of the proposition; and the *affirmation* of this connection is that which in both cases constitutes the proposition. Hence the proposition is denied in both cases by the denial of the existence of such connection. The proposition, "If A is B, C is D," is denied by saying, "Although A is B, it does not follow that C is D;" and in like manner the proposition, "Either A is B, or C is D," is denied by saying, "Neither A is B, nor C is D;" which means that "Though A is not B, it does not follow that C is D."

Again, although the proposition "Either A is B, or C is D," is denied by saying, "Neither is A, B, nor C, D;" yet *neither* and *nor* have a different relation to each other from *either* and *or*, the latter producing a disjunctive effect, which the former do not. "Neither is A, B, nor C, D," are simple negatives, in no way opposed to each other—establishing no opposition or connection between the two propositions, but merely amounting to the statement that A is not B, and C is not D.

The analyses shown to exist between Conditionals and Disjunctives will have prepared the reader to expect that the one may be easily reduced to the others; indeed, they are mere varieties of the same hypothetical proposition. "*It is either* the one *or* the other," means that "*If not* the one, *it is* the other." "*It is either* A *or* B," means that "*If not* A, *it is* B." Disjunctives are therefore reduced to conditionals, by taking as an antecedent the *contradictory* of one or more of the members; thus, "Either A is B, or C is D, or E is F," becomes a conditional by saying, "If neither A is B, nor C is D, E is F," or "If neither C is D, nor E is F, A is B," &c. "I see either a sail or a cloud," means "If I do not see a sail, I see a cloud," or "If I do not see a cloud, I see a sail."

III. The Dilemma.—The dilemma is a compound syllogism, partly conditional and partly disjunctive in its composition. It is defined by Whately, as a "syllogism with several antecedents in the major, and a disjunctive minor." It is a kind of argument in which two or more suppositions are placed before the mind in such a manner, that whichever term be accepted, a conclusion favourable to the reasoning point may be inferred. Hence the common expression of "being fixed on the horns of a dilemma."

There are two kinds of dilemma, the Direct or Constructive, and the Indirect or Destructive.

1. The Direct or Constructive dilemma may be either Simple or Complex.

(*a.*) A Direct *Simple* dilemma is one which has in the *major premiss* two or more antecedents all with the *same* consequent, and these antecedents being, in the *minor*, *disjunctively granted*, the one common consequent may be inferred as the conclusion, thus:—

> If A is B, *C is D;* and if E is F, *C is D;*
> But either A is B, or E is F;
> Therefore, *C is D.*

"This kind of argument," says Whately (in his *Easy Lessons on Reasoning*), "was urged by the opponents of Don Carlos, the pretender to the Spanish throne, which he claimed as heir-male, against his niece the Queen, by virtue of the Salic law excluding females, which was established (contrary to the ancient Spanish usage) by a former king of Spain, and was repealed by King Ferdinand. They say,

> "If a king of Spain has a right to alter the law of succession, *Carlos has no claim;* and if no king of Spain has that right, *Carlos has no claim;*
> But a king of Spain either has or has not that right;
> Therefore (on either supposition), *Carlos has no claim.*"

(*b.*) A Direct or Constructive *Complex* dilemma is one in which the antecedents have each a *different* consequent; and these antecedents being *disjunctively granted*, the consequents can only be inferred *disjunctively;* thus:—

> If A is B, *M is N;* and if C is D, *X is Y;*
> But either A is B, or C is D;
> Therefore, *either M is N, or X is Y.*

Or thus—

> If Prince Charles was rightful king, he deserved the crown; if he was a traitor, he deserved the gibbet;
> But he was either rightful king or traitor;
> Therefore, he either deserved the crown or the gibbet.

Or again—

> If men are unprincipled, they are knaves; if imprudent, they are fools;
> But most men are either unprincipled or imprudent;
> Therefore, most men are either knaves or fools.

2. An Indirect or Destructive dilemma has two or more antecedents, with each a different consequent; and these *consequents* (not the *antecedents*) being disjunctively *denied* in the minor premiss, the antecedents are disjunctively *denied* in the conclusion; *exempli gratia:*—

> If A is B, M is N; and if C is D, X is Y;
> But either M is not N, or X is not Y;
> Therefore, either A is not B, or C is not D.

> If duelling were lawful, it would not be prohibited; if expedient, it would not be condemned;
> But it is either prohibited or condemned;
> Therefore, it is either not lawful or not expedient.

Observe that, in this case, the minor disjunctively *denies* the consequents, although it is affirmative in form.

IV. *Relative Syllogisms.*—A relative proposition is that which consists of two categoricals, connected by the relative conjunctions, *when—then, where—there, as—so,* &c.; and that is a relative syllogism which, for its major premiss, has some such relative proposition; as,

> *When* the storm ceased, *then* I departed;
> But the storm ceased at noon;
> Therefore, I departed at noon.

> *Where* Christ is, *there* shall his servants be;
> But Christ is in heaven;
> Therefore, his servants shall be there also.

> *As* is the master, *so* is the servant;
> But the master is imperious and insolent;
> Therefore, his servant is so.

Arguments relating to the doctrine of proportion belong to this class of syllogisms; thus—

> As two to six, so three to nine;
> But two is one-third of six;
> Therefore, three is one-third of nine.

Or, $2 : 6 :: 3 : 9$; but $2 = \frac{6}{3} \therefore 3 = \frac{9}{3}$.

Regularly, the minor and conclusion would be—

> But two are to six in the relation of one-third to one;
> Therefore, three are to nine in the relation of one-third to one.

V. *Epichirema.*—A syllogism is so called, when to one or both of the premisses the proof is annexed; as—

> Truth will prevail, *for it rests upon a solid foundation;*
> Christianity is truth, *for it is attested by evidence which cannot be controverted;*
> Therefore, Christianity will prevail.

Sermons and other public addresses of an argumentative character, are frequently a series of syllogisms of this description. Epichirema, indeed, is not a peculiar kind of syllogism; but may be applied in the proof and development of any kind of syllogism whatever. The three propositions of any syllogism may be laid down as the heads of a discourse; and then the entire discourse will be a kind of Epichirema, the speaker demonstrating the premisses successively by every variety of argument, and thence inferring the conclusion. Of this character is Cicero's oration in defence of Milo, who had slain Clodius. His major proposition is, that *self-defence is lawful,*

or that it is lawful for one man to kill another who lies in wait to kill *him:* this he proves from the principles of justice, the customs of nations, the natural instinct of self-preservation, &c. His minor premiss is, that *Milo acted in self-defence*, which he proves by the fact that Clodius lay in wait for Milo, provided with arms, guards, &c. He then concludes that *what Milo did in self-defence was lawful*, namely, his killing Clodius.

VI. *Sorites.*—We adverted to this kind of compound syllogism in our Analytical Outline. (Chap. II.) It is a kind of continued syllogism, in which the predicate of the first proposition is made the subject of the next, and so on to any length, till finally the predicate of the last of the premisses is predicated of the subject of the first; thus, "Every A is B; every B is C; every C is D; every D is E;............every Y is Z; therefore, every A is Z." Or,—

Steam has produced railway travelling;
Railway travelling facilitates communication;
Facility of communication accelerates the despatch of business;
Whatever accelerates the despatch of business tends to the extension of commerce and manufactures;
Whatever tends to the extension of commerce and manufactures *increases the prosperity of the country;*
Therefore, *steam has increased the prosperity of the country.*

It is evident that this, and every sorites, may be divided into as many syllogisms as it contains middle terms. Here the minor term, or subject of the conclusion, is *steam;* the major, or predicate of the conclusion, *has increased the prosperity of the country.* All the rest are middle terms, or may be considered as repetitions, variations, or equivalents of one middle term. Divided into a series of syllogisms in *barbara*, the first would stand thus:—

Railway travelling facilitates communication;
Steam has produced *railway travelling;*
Therefore, steam facilitates communication.

The conclusion, "steam facilitates communication," is made the minor premiss of the next syllogism, and so on.

A series of conditional syllogisms may, in like manner, be abridged into a conditional sorites; as, "If A is B, C is D; if C is D, E is F; if E is F, G is H............if W is X, Y is Z; but A is B, therefore Y is Z." Or, "But Y is not Z, therefore A is not B." The one is a *Constructive*, the other a *Destructive* conditional sorites.

A *Sorites* admits of only one negative premiss, namely, the *last;* for if any of the others were negative, one of the syllogisms of the sorites would have a negative minor premiss, which is incompatible with the first figure.

VII. *Prosyllogisms.*—A prosyllogism is nearly allied to the sorites. It consists of two or more syllogisms so connected that the conclusion of the first forms one of the premisses of the next, and so on to the last; as, "A is B, B is C; therefore A is C; but D is not C; therefore, A is not D."

All men are fallible;
The greatest mathematicians are men;
The greatest mathematicians are fallible; therefore,
Though Newton was one of the greatest mathematicians,
Newton was fallible.

This differs from the *sorites* in commencing with one complete syllogism, while the conclusion of each may be either the major or minor premiss of the next.

VIII. *Enthymeme.*—The Enthymeme has been already explained. (Chap. II.) Though not a compound, but a defective syllogism, we mention it in this place, to render our list of the *informal* syllogisms complete. As formerly stated, the Enthymeme is a syllogism, one of whose premisses is suppressed. This is of common occurrence, both in writing and speaking, for it would generally be found tedious to draw out every argument in mood and figure. But if there be any doubt as to its soundness, the syllogism must be completed by adding the absent proposition. This may be either the major or minor premiss, and which of the two is wanting may easily be known by the conclusion. Thus—

Kings are mortal, for they are but men;

Or,

Kings are but men;
Therefore, kings are mortal,

evidently wants the major premiss; for that which is stated contains the minor term (viz. the *subject* of the conclusion, kings), and therefore must be the minor premiss. Again—

Kings are mortal, for all men are so;

Or,

All men are mortal;
Therefore, kings are mortal,

evidently wants the minor, for a like reason.

IX. *Induction.*—In most logical treatises, the argument so well known under the name of Induction (by which, from several particular propositions, one general proposition is inferred), is classed as a peculiar form of syllogism, and therefore discussed under this head. It is, however, too important to be adequately treated at the end of a division, and therefore we postpone it as a subject deserving of separate consideration. We do not consider Induction (properly so called) as an argument, but as affording merely the basis of what may be termed an *inductive argument*, or, as Whately justly expresses it, an argument *from* induction. But this is a subject which will be fully discussed in a future chapter.

Part IV.

OF FALLACIES OR SOPHISMS.

It is an axiom, that from truth nothing can really follow but what is true. A false conclusion, therefore, either does not follow from the premisses, or *one* at least of the premisses must be false.

A true conclusion, however, may be *correctly* deduced from premisses, one of which is false. The truth of the conclusion, therefore, does not necessarily imply the truth of the premisses. Thus, the example already given—

All bodies moving round the Sun are planets;
Neptune moves round the Sun;
Therefore, Neptune is a planet,

is false in the major premiss; yet the conclusion is correct, and logically follows from the premisses.

But if the premisses be true, and the reasoning correct, the conclusion must necessarily be true also.

At the same time, as has been repeatedly stated, it is not the province of logic to determine the truth of the premisses. This belongs to other sciences, according to the nature of the subject under discussion. Logic proceeds on the assumption that certain premisses are true, and teaches only the art of reasoning correctly from given premisses.

But the same principles and rules which teach to reason correctly, teach likewise the art of detecting unsound arguments. Such an argument, so framed that its inconclusiveness or insufficiency is not immediately apparent, is termed a *fallacy* or *sophism.*

These words, indeed, are not exactly synonymous; they may be distinguished from each other, and must at the same time be distinguished from *falsity* and *falsehood*—two words somewhat analogous, though widely different in meaning.

Falsity signifies the verbal expression of what is not true, whether believed or not by the person expressing the untruth, but implying no intention to deceive. *Falsehood* is the utterance of what is not true, with intention to deceive.

A *fallacy* is an unsound argument, having the appearance of being sound, and which may be considered valid by the person using it. A *sophism* is generally regarded as a fallacy framed with intention to perplex or deceive.

A sophism, therefore, stands in nearly the same relation to a fallacy, as falsehood to falsity. The two latter words have reference to truth, the former to reasoning. All sophisms may, in a logical treatise, be considered fallacies; for, to the logical inquirer, it matters not with what intention an unsound argument has been uttered. His business is simply to discover and demonstrate in what its unsoundness consists.

Archbishop Whately gives the best enumeration and classification of fallacies. He defines a fallacy as "*any unsound mode of arguing, which appears to demand our conviction, and to be decisive of the question in hand, when in fairness it is not.*" On this subject he adds—"After all, in the practical detection

of each individual fallacy, much must depend on natural and acquired acuteness; nor can any rules be given, the mere learning of which will enable us to *apply* them with mechanical certainty and readiness: but still we shall find, that to take correct general views of the subject, and to be familiarized with scientific discussions of it, will tend, above all things, to *engender such a habit of mind* as will best fit us for practice."

Whately divides fallacies into three classes—Logical, Semi-logical, and Non-logical or Material. 1. *Logical* fallacies are those in which the conclusion does not follow from the premisses, and which exhibit their fallaciousnes by the bare *form* of the expression, without any regard to the *meaning* of the terms. 2. *Semi-logical* fallacies agree with logical in this, that the conclusion does not follow from the premisses; but to discover that it does not, requires attention to the *meaning* of the middle term, and some knowledge of the subject; "so that here," as Whately remarks, "Logic teaches us not *how to find* the fallacy, but only *where to search* for it, and on what principles to condemn it." 3. *Material* or *Non-logical* fallacies are those in which the conclusion follows from the premisses, but is not decisive of the question, either because it is not the conclusion required, or because the premisses are such as ought not to have been assumed.

Adopting this classification, we shall enumerate, with examples, the principal forms of fallacies under each head.

I. LOGICAL FALLACIES

Are those in which the conclusion does not follow from the premisses, and which may be shown to be fallacies by merely applying the logical rules, without regard to the meaning of the terms. To this class belong—1. Undistributed middle; 2. Illicit process; 3. Negative premisses, or affirmative conclusion from a negative premiss; and 4. Those which have more than three terms expressed.

The greater part of this class of fallacies have been already explained, in laying down the logical rules of which they are severally violations.

Archbishop Whately, acting, we presume, on this consideration, substitutes for special examples of each a general dissertation on the importance and difficulty of detecting and describing fallacies—a topic by no means foreign to the subject, but which would be much more appropriate in the shape of an introduction. Indeed, with all its acumen and ability, Whately's work is singularly destitute of lucid methodical arrangement. We prefer, at the risk of some repetition, to give particular illustrations of each of the sources of fallacies above enumerated.

1. *Fallacy of Undistributed Middle.*—Fallacies of this description consist in a violation of Rule I. (Chap. V.), according to which the middle term must be distributed, or taken universally, once at least in the premisses, and must therefore, in one of them, be either the subject of a universal or predicate of a negative. The following may be given as an example of this fallacy:—

Tyrants and oppressors are *objects of general hatred,*
Nero and Caligula were *objects of general hatred;*
Therefore, Nero and Caligula were tyrants and oppressors.

In this example, both the premisses are true, and the conclusion *happens* to be true, but does not follow from the premisses. It is when the conclusion is true, or not obviously false, that fallacies in general are apt to escape detection. Nothing, however, is more pernicious, or more detrimental to a good cause, than even to support the *truth* by fallacious arguments; for, if the fallacy in such cases happens to be discovered—as sooner or later it will be—the cause inevitably suffers, and even the truth is discredited, though standing on independent ground.

The syllogism, or apparent syllogism, above given, is exactly equivalent to the following: "Sheep are animals; oxen are animals; therefore, sheep are oxen." Here, as in the former example, the middle term is distributed in neither of the premisses; because it is the predicate in both, and both are affirmative. The minor and major terms may therefore *happen* to be compared with different parts of the same middle term. This is obviously the case in the second example. Sheep are *some* animals; so are oxen; but they are not affirmed to be the *same* animals. Tyrants and oppressors are *some* "objects of general hatred;" so were Nero and Caligula; but others (even the best of men) may be objects of general hatred as well; it does not follow from the premisses, therefore, that Nero and Caligula were tyrants and oppressors, although there can be no doubt of the fact. In this case the major and minor terms may, and do, correspond to precisely the same part of the middle term; but this is not implied in the *form* of the expression. Substitute unmeaning terms, A, B, C, and this will not appear. Exactly the same *form* might be used to prove that the apostles were bad men, assuming for a middle term the truth of Christ's prediction—"ye shall be hated of all men for my name's sake."

2. *Fallacy of Illicit Process.*—This fallacy consists in a violation of Rule II., which affirms that the terms in the conclusion must not be taken more universally than in the premisses. The terms which appear in the conclusion are the major and minor; and therefore an *illicit process* is confined to one or other of these. The following examples will be sufficient:—

ILLICIT PROCESS OF THE MAJOR TERM.

Those who befriend us *ought to be treated with kindness;*
Our enemies do not befriend us;
Therefore, our enemies *should not be treated with kindness.*

ILLICIT PROCESS OF THE MINOR.

Nothing that is necessary to life should be wasted;
Food is necessary to life;
Therefore, *no food* should be wasted.

The truth of the conclusion in this second example disguises the fallacy. It cannot be affirmed, however, that *all* food is necessary to life. The minor premiss, therefore, merely asserts that *some* food is necessary, while it is affirmed in the conclusion that *no food* should be wasted. This may be, and is, prefectly true; but the premisses only warrant the inference that "*some* food should not be wasted"—so much, namely, as agrees with the middle term, "necessary to life." Take the following precisely analogous case, and the fallacy will be apparent at once:—

Nothing that is necessary is sinful;
Conversation is necessary;
Therefore, *no conversation* is sinful.

Here it will be seen that the minor term *conversation* is taken universally (*i.e.* distributed) in the conclusion, while in the minor premiss it is used in a limited sense, and can only mean *some* conversation. This is what is meant by an *illict process of the minor.*

In the first example, "Those who befriend us," &c., a similar process occurs with reference to the major term, "*Ought to be treated with kindness.*" This term, being the predicate of an affirmative, is not distributed in the major premiss; but in the conclusion it is distributed, being the predicate of a negative. The major premiss asserts that "Those who befriend us ought to be treated with kindness," but does not assert that these, *and no others,* ought to be so treated; whereas, in the conclusion it is assumed that all who do *not* befriend us should *not* be treated with kindness. This is, therefore, an *illict process of the major.*

3. *Fallacy of Negative Premisses, or affirmative conclusion from a Negative premiss, and vice versâ*—

(*a.*) The fallacy of negative premisses involves a violation of Rule III., which asserts, that from two negative premisses nothing can be concluded. Any apparent argument, therefore, in which the premisses are both negative, may be discarded with perfect safety as no argument at all. The pretended conclusion, whether right or wrong, cannot follow from the premisses; for these, being both negative, merely affirm that the minor and major terms (the subject and predicate of the conclusion) both *disagree* with a third term; and therefore it still remains undetermined whether they agree or disagree with one another. Thus,

Cunning is not always the best policy;
Honesty is not cunning;
Therefore, honesty is always the best policy,

is really no argument, though the conclusion may be true; for

although *cunning* is not the *best policy*, it does not follow that everything which differs from cunning (say, *simplicity* or *folly*) is the best policy.

So obvious is the fallacy of such an apparent argument, that it could only be used with effect in some elliptical form, as the *enthymeme*, or by involving the question in a cloud of words.

(*b.*) A negative conclusion from two affirmative premisses would be, in like manner, a violation of Rule IV., and must therefore be a fallacy; for, by that rule, a negative conclusion cannot, in the nature of things, result from two affirmative premisses. Both premisses being affirmative, assert that the minor and major terms both *agree* with a third, namely, the middle term, and therefore must agree with one another; so that the major can only be *affirmed*, not *denied*, of the minor.

In a recent work on logic, the following are given as examples of this fallacy:—

All native industry ought to be protected;
All the labours of our artisans, agriculturists, authors, &c., constitute our native industry;
Therefore, none of the labours of foreign artisans, agriculturists, authors, &c., ought to be protected.

All men should purchase in the cheapest market;
The cheapest market is where the best goods are got for least money;
Therefore, no man should purchase anywhere but where the best goods are got for the least money.

The first of these examples is good, as an illustration of the fallacy in question; for although it may be quite true that none of the labours of foreigners ought to be protected, the premisses warrant no conclusion except that the labours of our own artisans, &c., ought to be so, which, although a *valid* conclusion, would perhaps be less *true* than that which is fallaciously deduced. The second example, however, is not a fallacy at all, although it is given as such by the author of "*The Art of Reasoning.*" The conclusion, drawn in regular form, would be this:—

All men should purchase where the best goods are got for least money;

which, when converted by negation (or contraposition) is precisely equivalent to saying—

No man should purchase where the best goods are *not* got for the least money;

the very conclusion above deduced, though slightly different in expression. This conclusion, in short, though seemingly negative in form, is really affirmative. Learners must beware of confounding with negative propositions, those that involve a double negative, which is equivalent to an affirmative.

(*c.*) An affirmative conclusion, when one of the premisses is negative, must be a fallacy, as contrary to Rule V., which asserts, that if one premiss be negative the conclusion must be negative. When one of the extremes agrees and the other disagrees with the middle term, it is evident they cannot agree with one another; that is to say, their relation cannot be stated affirmatively. Hence there must be something logically defective in the following argument:—

Gold cannot support existence;
Food supports existence;
Therefore, food is better than gold.

Quite true; the conclusion is sound, but does not logically follow from *these* premisses. From our knowledge of the subject, we are aware that *what supports existence is better than what does not support existence;* but this, though assumed in the conclusion, is not implied in the premisses. To render the argument complete, this must be made the major premiss:—

What supports existence is better than what does not,
Food supports existence, gold cannot;
Therefore food is better than gold.

Even this is a compound syllogism, having as its minor premiss two independent propositions. To bring it completely under logical rules, it must be resolved into its elements, in two syllogisms, as follows:—

What supports existence is better than what does not;
Food supports existence;
Therefore, food is better than what does not.

Something that does not support existence is gold;
Food is better than what does not support existence;
Therefore, food is better than gold.

This is the argument stated at full length. Even in its first form, however, it is quite sufficient for ordinary reasoning, and could not properly be termed a fallacy, unless it were attempted to palm off in such a form some unwarrantable conclusion, such as the following:—

Sir Isaac Newton could not resolve light into three primary colours;
Sir David Brewster has done so;
Therefore, Sir David Brewster is a greater optical philosopher than Sir Isaac Newton.

To show the fallacy of the conclusion, the argument has only to be stated at full length, as in the preceding instance, and then it will be sufficiently obvious. Logic does not require that all arguments should be so analysed, but teaches the method of doing so, and thus of testing their soundness when any fallacy is suspected.

4. *Fallacy of more than three terms expressed.*

Both the undistributed and the ambiguous middle are virtually equivalent to the introduction of four terms. The case of undistributed middle has been already considered, and that of ambiguous middle will constitute the subject of our second division, or semi-logical fallacies. Under the present head we class those apparent syllogisms in which there are more than three terms palpably or positively expressed, or which, when stated at full length, must so express them. The fallacy last given may serve as an instance of this, as well as of the special subdivision (*c*) under which it is adduced; for often the same fallacy may be referred to different heads. Thus, in the conclusion, the major term, *a greater optical philosopher than Sir Isaac Newton*, does not occur in the premisses at all, and therefore is really the *expression* of a new or fourth term.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER VI.

An important change was now at hand. Research was still discouraged in various ways, but no one, after Galileo, was openly and judicially condemned for philosophical speculation. But we shall be very blind, if we suppose that all hostility to thought has passed away with the stake and the dungeon. Denunciation and calumny now take the place of the open persecution, and appear as the "Inquisition rebaptized"—the old brute torture spiritualized. A catalogue of prohibited works is still issued at Rome, in which appear the writings of Plato, Bacon, Newton, Humboldt, and Comte. Bacon's new method in philosophy; Harvey's discovery of the circulation; Newton's researches in astronomy; Locke's investigations on the human mind; Franklin's lightning rod; and Jenner's discovery of vaccination, have all been denounced in language which proved that the enemies of philosophy, if less powerful than of old, are no less malignant. The Royal Society;* the Society for the Diffusion of Useful Knowledge;† the British Association; the London University; Mechanics' Institutions; the Queen's Colleges in Ireland, have all passed through a shower-bath of abuse. Cultivators of geology have been within the memory of the present generation attacked with a mixture of billingsgate and bigotry, which makes us blush for the vaunted intelligence of our era.

The *Quarterly Review* even puts forward this statement:—"Let us not discourage science in itself, nor refuse gratitude to its promoters (how very liberal!), but let us place it, *at least*, under the control of the Christian church." *At least*, and what at most? What more than this absurd and unjust control did the priests demand in the darkest ages? These facts should

* The Rev. R. Crosse, of Somerset, charged the fellows with neglecting the wiser ancients, seeking the guidance of their own unassisted judgments, and endangering the safety of the established church (!), by admitting among them men of all countries and all religions. He further stated that "experimental philosophy would overthrow Christianity."

† For tirades against the latter bodies, see the *Quarterly Review* and the *Christian Observer*.

lead us to very serious reflection. It is in vain, then, that Galileo has established the great doctrine of the compromise; in vain the enlightened Chalmers proclaimed that Christianity has "everything to hope and nothing to fear" from the pursuit of science; in vain that the most able and intelligent divines, such as Whately, Powell, Maccombe, point out that there is no real discrepancy between the universe and the scriptures, if we set false interpreters aside—the unblest strife still continues!

There is yet a remark which we cannot in justice suppress, since we wish not to be quoted for the applause of inebriate shipwrights at Liverpool "Protestant meetings." To proclaim the persecution of science to be in any way connected with the doctrines of the Catholic church, seems to us absurd. If Catholicism has been hitherto practically the greatest persecutor of science, we must seek the cause simply in its wide extent, its prevalence during rude ages, its civil power—in a word, from its being the type of an ecclesiastical corporation. In Protestant churches there have been, and still are, large parties, who, if their own words belie them not, are as hostile to science as were ever the fathers of the holy office.

Turning from these painful even though necessary contemplations, we proceed to a highly interesting, though still obscure subject—

THE OCCULT SCIENCES.

Strictly speaking, this expression is self-contradictory. Whatsoever is occult, is not, in the highest sense of the word, science. Under this protest, however, we shall continue to use a term which has become general, and which it might not be easy to replace. During the last century, and at the beginning of the present, the subject of this chapter was consigned to utter neglect, or characterized at most as a tissue of aimless, useless, and contemptible aberrations. Now, on the contrary, we recognise in it not merely an interesting phase in the education of the human race, but we detect the germs of most valuable ideas amidst its visionary conjectures.

Under this one head we find arranged, or rather confounded, matters distinct and heterogeneous—on the one hand, astrology and alchemy, and on the other, necromancy and witchcraft. No association could be more unfortunate. The former we must pronounce as conceptions progressive in their tendency, as supplying man with motives for observation and experiment, and as thus paving the way for exact science. The latter were remnants of heathen superstition, retrograde in their nature, and calculated to wither and benumb the powers of the human mind.

Astrology was not peculiar to the middle ages. We may trace its existence long prior to the dawn of what is commonly termed classical antiquity; and even yet, it finds a number of votaries. Its fundamental idea is, simply, that the heavenly bodies influence the destinies of men and nations; and that, by observing the former, we may foretell the latter. In ancient times, when the personifying spirit was still dominant, the stars were viewed as deities, and their influence as spiritual. The astrology of the middle ages considered the astral emanations as purely physical. The entire conception, so far from being absurd and irrational, was, at the time of its formation, eminently scientific. In the motions of the heavenly bodies alone, man had detected law and order—what more philosophic than for him to attach to these ascertained uniformities all other phenomena, even those of the social and moral world? Those theorists who, in our day, endeavour to account for psychological facts on electrical or chemical principles, fall into precisely the same error—an error less pardonable now than it was four centuries ago. But was it not strange, you will ask, that the physician should consult the aspect of the stars before bleeding a patient, or administering a remedy—that the chemist should note under what celestial aspect every experiment was performed? By no means: that the position of the stars is without appreciable influence upon physical, chemical, or physiological phenomena, is a truth which could not be known *à priori*—which could only be established by direct observation. In experimental research, we are bound to take into account every circumstance which is not already known to be inoperative. The mediæval philosophers in this proceeding showed a fine sense for the general harmony of the universe—for the inter-connection of all phenomena, worthy of the highest praise. How much farther should we have been advanced in chemistry had modern inquirers noted down whether their experiments were performed in the presence or absence of direct sunlight! Astrology had another important function in the education of the human race; it supplied a most urgent motive for constant and accurate astronomical observation. It is idle to object, that even in antiquity such observations were occasionally undertaken quite independently of astrological purposes. If man is successfully to interrogate nature, he must have some definite tangible object in view; and it is only in the most advanced state of society, and in the most eminent individuals, that this object is the love of speculative truth. Ancient superstitions sought to foretell future events by an observation of the clouds, thunder, &c., and by inspecting the entrails of animals sacrificed. Here we see the cradle of meteorology and of anatomy. With all these merits, astrology is still tainted with the fundamental error of the primitive philosophy. It proceeds from the principle of "man the object and measure of all things"—a doctrine even yet not totally eliminated. By many of its professors it was blended with a mysticism, the remnant of earlier epochs. The history of astrology is too closely intertwined with that of astronomy to require separate treatment. We must distinguish among astrologers two classes—the one sincere, enlightened, philosophic; the other a band of mere unblushing impostors. The modern professors of astrology—for such still exist—belong, we fear, mostly to the latter class. Popular ignorance, occurring as it does in all quarters, affords them an easy harvest. Since the mass of mankind have renounced astrology, not in accordance with reason, but simply in deference to a few great names, we will briefly state the arguments for its rejection. If the destiny of a man through life depended upon the position of the planets at the time of his birth, two individuals born at the same time, and in the same place—an occurrence far from uncommon in populous towns—would experience throughout life similar fortunes. This argument we find very forcibly urged by Cicero. Again, the majority of physical and chemical phenomena are found to be perfectly independent of the position of the stars. Even the physical influence of the moon appears to vanish upon a more exact scrutiny. *A fortiori*, then, we may infer that physiological and social events will be unaffected by the heavenly bodies. The strongest argument against astrology is, however, the absence of any clear definite accomplishment of its predictions. The astrologers, ancient and modern, couch their prophecies in vague, ambiguous phraseology. They speak the language of a man anxious to provide for a safe retreat. Now, if any astrologer feels convinced of the goodness of his cause, the test is open. Let him draw up, in clear precise terms, a statement of the progress of the war during the next two years, and deposit it, sealed with the Royal Society or the Institute of France. If the document, when opened at the expiration of the term, agrees with recorded events, astrology is triumphant. But, till this or some similar test shall have been triumphantly undergone, the art must still continue to rank as a delusion, and its exercise for gain must still be considered by the law, a method of obtaining money under false pretences.

Much of what we have already observed will apply to alchemy. If astrology seemed to offer man a complete insight into futurity, alchemy promised him the power of modifying nature to his advantage. We may readily conceive, that had not such glittering incitements to research been held out, the natural sluggishness of our race would have recoiled from its tremendous task; the interpretation of the universe and mankind would have remained in comparative barbarism. It was in seeking the philosopher's stone that man became encouraged, trained to experimental inquiry; that he invented instruments and operations, and discovered so many useful substances as fully to compensate for the failure of his original hopes. The origin of alchemy—the transmutation of the cheaper metals into gold—is lost in the most remote antiquity, in the grey dawn of human development. Abou Moussah Dschafar Al Soli (Geber), who flourished in the 7th or 8th century, and

Suidas in the 11th, are the earliest authenticated writers who speak of the great transformation. They treat it, moreover, not as a recent idea, but as a tradition handed down from the earliest ages. Suidas relates how the Emperor Dioclesian, out of jealousy, persecuted the Egyptian alchemists, and burned their writings. The Argonautic expedition, which chronologists have fixed for their own amusement about B.C. 1200, he considers to have had for its object the possession of an alchemical treatise.

Geber* considers all the metals as compounds of *mercury* and *sulphur*, a notion adopted from predecessors whom he styles the "ancients." By the application of the *philosopher's stone*, or, as he elsewhere calls it, the *medicine* or *magistery*, the impure or unclean metals could be healed or converted into silver and gold. The preparation of medicines, however, and not gold-making, was the object of Geber. To the latter, his allusions are only incidental. But much earlier and more directly bearing on the point, is the supposed manuscript of Zosimus of Panapolis. This work, dated in the fifth century, is said to exist in the Royal Library at Paris, where two men only, Olaus Borrichius and Scaliger, have been able to find it. From their extracts we learn that the art was communicated to mankind by a tribe of angels or genii prior to the Noahic deluge;† that it was practised by Tubalcain, and thus handed down to the patriarchs and wise men of the primeval world. Other mediæval authors seek for the cradle of alchemy in Egypt—that land which, by its silence, often passes for wise—and assign the discovery to Hermes Trismegistus—whence the name "Hermetic art." Alexander the Great, in one of his expeditions, found, we are told, the sepulchre of Hermes filled with inestimable treasures. Here too, engraved on a tablet of *zatadi* or emerald, was a mystical inscription in the Phœnician tongue, embodying the entire secret. Others assert that a woman named Sarah found the tablet in a cave near Hebron. We subjoin the inscription for the benefit of such of our readers as may be able to discover its hidden sense.

"*The words of the secret of Hermes Trismegistus.*

1. I speak sure and certain truth without falsehood.
2. What is below is as what is above, and what is above as what is below, to accomplish the miracles of the one thing.
3. Like as all things were produced by the word of the Only One, so all things are perpetually generated from this one thing by the disposition of nature.
4. Its father is the sun, its mother the moon; it was borne in the womb of the air, and its nurse is the earth.
5. It is the cause of all perfection throughout the whole universe.
6. It reaches the highest perfection of power if it return into the earth.
7. Separate the earth from the fire, the gross from the subtle, acting gently, and with much judgment.
8. Ascend from earth to heaven, and return thence again to the earth, and gather into one the powers above and below; so thou shalt possess the glory of the whole world, and all obscurity shall depart from thee.
9. This is a thing stronger than all fortitude, because it binds everthing fugitive, and pervades everything solid.
10. Thus was the world created.
11. Hence proceed marvellous works, of which this is the manner.
12. Therefore am I called Hermes Thrice-greatest, having three parts of the wisdom of the whole world.
13. What I have said of the operations of the sun is finished."

In another pamphlet ascribed to Hermes,‡ a recipe for the great operation is given, all the ingredients but one being unintelligible:—"Take of moisture an ounce and a half; of meridianal redness, that is, the soul of the sun, a fourth part, that is half an ounce; of yellow *seyr* half an ounce; and of auripigmentum half an ounce, being three ounces. Know that the vine of the wise is extracted in threes, and its wine, lastly, is perfected in thirty."

There is every reason to believe that all the extracts ascribed to Hermes are forgeries of a much later date. Had the emerald tablet been really discovered in the campaigns of Alexander, it could never have escaped the notice of Aristotle, and the philosophers of the Alexandrian school. If alchemy had in any prominent manner occupied the attention of the Egyptians, it would in all probability have been mentioned by Herodotus. Yet neither in him, nor in any Greek or Latin author before Suidas, does the word chemistry occur. The silence of the Scriptures goes to establish the absence of alchemy in Phœnicia. The very name of Hermes Trismegistus—in Egyptian *Thoth*—is mythological. *Thoth* signifies a pillar or obelisk. On pillars was inscribed the philosophy of the Egyptian priesthood, and as *three* successive sets of inscriptions were known to exist, we can easily understand how the last and most perfect became personified under the name Hermes Trismegistus the discoverer, the author of volumes thirty thousand!

Alchemy, therefore, found its earliest known cultivators in Arabia. Thence it was transmitted to Europe, blended with the scholastic-peripatetic philosophy, and flourished until ultimately decomposed by Paracelsus. Before treating of the career of its great upholders, a short analysis of the leading doctrines of alchemy may be needful. Let us, in the first place, remark, for the benefit of those unfledged witlings who sometimes affect to sneer at a Roger Bacon or Albertus Magnus, that there is nothing absurd in the idea of transmutation. If the Hermetic art has been practically abandoned, its impossibility has never been demonstrated. True, we regard gold and silver, like the rest of the metals, as simple elementary bodies. But what is an element, according to the first authorities? Simply a body which, up to date, we have not been able to decompose. To-morrow, for anything we know to the contrary, gold or some other of these substances may be decomposed, and again re-formed from its constituents. The alchemists believed that all substances were formed from three elements combining in various proportions, *salt*, *sulphur*, and *mercury*. Not, we must remember, the concrete, tangible bodies known under those names, but types or abstractions standing for whole classes of things. Salt denoted fixity, solidity, firmness; sulphur represented combustibility; and mercury the volatile, the fugitive. Under these three heads, therefore, were embodied some of the most prominent chemico-physical phenomena, calculated to strike the early inquirer. Some of the metals they supposed contained a larger proportion of one or other of these elements, and, by altering these proportions, lead would of course be convertible into silver, or copper into gold. The sulphur and mercury contained in gold and silver were likewise considered as more *perfect* in their nature than those found in the baser metals. This expression, formerly branded as involving notions totally unchemical, may be merely an unapt embodiment of the idea of allotropy. We are acquainted with varieties of sulphur differing widely among themselves, though we do not designate them as "perfect" or "imperfect." The alchemists attached great importance to *time*. They would oxidize and reduce mercury twenty times, in the opinion that its properties would thus undergo some remarkable exaltation. After a distillation, the product obtained was returned to the retort, and again distilled time after time. Fusions, digestions, calcinations, were prolonged for a period of forty days—a philosophical month. Till quite recently this idea has been viewed with ridicule among the moderns; chemical action being pronounced instantaneous, and a prolonged exposure of substances to any influence perfectly useless. Now, however, it has been observed that bodies left for a considerable period together, undergo modifications quite peculiar, and totally distinct from the reaction obtained on mere momentary contact. Chemistry, therefore, has its dynamics as well as its statics. If this one idea points our way into a totally novel region of investigations, investigations destined to shed a clear light upon many of the deepest mysteries of the universe, let us not forget to thank the alchemists with whom it originated. In their "philosophical month," we see the germ of the operations by which Gaudin and Becquerel have succeeded in the artificial preparation of crystalline minerals, and of the interest-

* A Latin translation of Geber's works appeared at Strasburg, 1529. An English version was edited by Richard Russel in 1678.

† Genesis vi., 2, 4.

‡ Tractatus aureus de lapidis physici secreto.

ing conclusions of Liebig and Williamson on etherification. Truly, the alchemists were nobler, greater, than their most exalted ideals. We have already alluded to the care taken by these sages to note down the celestial aspect under which their experiments were performed, and have pointed out the high philosophical sense manifested by this precaution. Some of them even believed that they could trace in chemical phenomena a certain periodicity—results being attainable only after the lapse of a given cycle of years. This idea, entertained as late as the commencement of the present century by Winterl, has not been hitherto supported by facts.

Another most important feature of alchemy is the mystical religious spirit in which its operations were undertaken. The formulæ of the adepts were interspersed with prayers, invocations, and thanksgivings; the aid and protection of the saints were earnestly sought for, and whilst the fracture of a crucible or the spilling of a solution was ascribed to the malign influence of evil spirits. The chemical forces were all personified; the substances operated upon described under symbolical names.* The tendency is so strongly manifested, that it is not always easy to discriminate between real alchemical treatises, and works on mystical theology garnished according to the fashion of the times with alchemical allusions.† To increase the confusion, many of the patriarchs, prophets, and evangelists were supposed to have been adepts, and certain passages of scripture were considered to refer to the great work of transmutation. We need not hesitate to consider alchemy as the supernatural, personifying phase of chemical philosophy.‡ The greater complexity of the science will explain why its development should be so much more tardy than that of mathematics, astronomy, or certain branches of physics.

The substance by whose presence the change was to be effected, was currently styled the "philosopher's stone"—generally described as a red powder. To this stone was ascribed not merely the transmutation of metals, but the healing of all diseases. Hence it is called the elixir of life, or of immortality. These attributes were ascribed to gold itself, by a train of fallacies easy to be recognised. As the object of universal desire and wonder, it must, of course, possess all desirable and wonderful properties. This opinion of the medicinal functions of the philosopher's stone became gradually more prevalent, and effected, at last, the downfall of alchemy in its original signification. Another substance eagerly sought for was the *alcahest*, or universal solvent—an expectation to some extent realized by the modern discovery of fluorine. Minor undertakings were the restoration of a plant or flower from its ashes—the production of animals or men without the intervention of parents of their own species. Man had learned his power of modifying the course of nature by the aid of science, but had not yet learned to exercise it with wisdom and moderation. The great error of these old experimentators was economical, not chemical. They forgot that, even granting the abstract possibility of transmutation, the expense of the operation might still outweigh the value of the product, and gold-*making* prove as precarious as gold-*mining*. They forgot, moreover, that gold, though universally selected as the symbol of wealth is not wealth itself, but, like all other commodities, is subject in its price to the laws of supply and demand. An individual gold-maker whose labours should prove successful, would doubtless amass great riches. Were the process known even to a few persons, the supply must speedily outstrip the demand. What, therefore, can we think of the man, who, in the advertising columns of the "Athenæum," has, within the last ten years, offered to teach the hermetic art for a premium of one hundred guineas? Let us now turn to a survey of the more eminent alchemists.

Albertus Magnus, born at Bollstaedt, or, as others say, at Lauingen, in Suabia, about 1193, leads on the series. He studied at Padua, became professor at Cologne and at Paris, was made provincial of the Dominican order in Germany, and was at last raised to the bishopric of Regensburg. He soon, however, resigned the mitre, and returning to Cologne, ended his days in a cloister, A.D. 1282, in the renown of learning and the odour of sanctity. His lucubrations were bequeathed to posterity in the shape of 21 goodly folio volumes.* Like the generality of mediæval sages, his labours were encyclopedic. In the peripatetic philosophy of the day, he attained such eminence as to be dubbed "*the ape of Aristotle*," a title nowise dishonourable in those days. It is not, however, his metaphysics or his scholastic theology which now gain attention. We could now, if need were, construct machinery capable of composing such works *ad infinitum*. But Albertus had some dawning idea of chemical analysis, and possessed a sound, practical insight into the treatment of ores and the extraction of metals. This proves, that while toiling diligently after the golden ideal of the age, he had an eye for researches of a more tangible nature. He wrote also upon physics, and attained a clear insight into the distribution of heat on the earth's surface. Seen through the glass of popular superstition, Albertus assumes a very different aspect, and appears as a full-blown necromancer. Being about to entertain some great personage, he caused, it is said, tables to be spread in his garden, though it was the middle of winter. No sooner were the guests seated, than the sun shone out from a summer sky, the snow vanished, the trees were covered with foliage, and the air was filled with the harmony of birds and the perfume of flowers. As soon as the banquet was ended, winter returned in all its former rigour. Perhaps the real truth of this strange story is, that the worthy sage had erected a kind of conservatory. He is also said to have manufactured an *androides*, or artificial man, which aided him in his studies. Was this a calculating machine?

The celebrated Dominican, Thomas of Aquino (Aquinas), a pupil of Albertus, though chiefly known for his scholastic lore, wrote also a few tracts on alchemy, remarkable chiefly for their obscurity. In his writings, we first find the term *amalgam* applied to mercurial alloys. He was born at Rocca Sicca in Naples, A.D. 1224, and died 1274.

Higher than either of these stands our countryman Roger Bacon, the greatest thinker of the middle ages. Having touched upon his career in the foregoing chapter, we will here simply remark that he considered the metals as compounds of mercury and sulphur; and that he was acquainted with the peculiar nature of manganese and bismuth. Besides his three larger works, Bacon wrote a number of chemical tracts, many of which are still unpublished.

Turning southwards, we find Spain, commonly barren in thinkers, offering to our view a most remarkable character. Raymond Lully, born in the isle of Majorca, A.D. 1235, reminds us of Priestly. At once soldier, monk, missionary, logician, alchemist, and physician; his very identity has been doubted, and some authors have endeavoured to establish the existence of two Lullys, the one a theologian, and the other a chemist. His life is not without romantic adventures. Sprung from a rich and noble family, he spent his youth in warlike enterprise and in dissipation. Horrified at discovering that a lady to whom he was passionately attached (and whose attention he had sought to gain by entering a church on horseback during

* Thus sal-ammonaic bears in the writings of the alchemists the following names: the sensitive soul; the water of the two brothers out of the sister; the eagle; the eagle stone; the crab; the stone of the combining angel. The combination of gold and mercury, and the consequent solidification of the latter, is expressed thus:—"If thou put the lion and the eagle into a crystal den, the eagle shall devour the lion, and hereafter fall into a deep sleep." Here is one of their formulæ:—"To make the elixir of the wise, take, my son, the mercury of philosophers (lead), and calcine until it become a green lion (litharge). Continue the calcination until it is transformed into a red lion. Digest this red lion in the sand-bath, the acid spirit of grapes (vinegar), and the mercury will become a gummy substance. Place this gummy matter in a luted cucurbit, and distil gently, collecting separately the products which appear of different natures. Thou wilt obtain an insipid flegm, then a spirit, and red drops. The cymmerian shades will cover the cucurbit with their dark veil, and thou wilt find within a true dragon, who gnaws his own tail (metallic lead finely divided). Take this black dragon, bruise him upon a stone, touch him with a live coal, he will ignite, and taking a glorious citron colour, reproduce the green lion. Let him swallow his tail (return him to the cucurbit), and rectify carefully, and thou wilt see appear the burning water and the human blood (pyroxitic spirit and a red empyreumatic oil).

† Thus Jacob Böhme, the mystic of Görlitz.

‡ That Liebig could deny the evolution of science through three successive phases—an evolution nowhere more glaringly manifest than in chemistry—is hard to explain. But a philosopher who has gone so far as to *threaten* to refute and suppress whatever is brought forward by his contemporaries, must not be surprised if his words and actions should be ascribed to sinister motives. (See a letter of Berzelius, published in the Phil. Mag. and the Pharmaceutical Times, Vol. III., p. 652.)

* The chemical works of Albertus are:—"De rebus metallicis et mineralibus." "De alchymia." "Secretorum tractatus." "Breve compendium de ortu metallorum." "Concordantia philosophorum de lapide." "Compositum de compositis." "Liber octo capitum de philosophorum lapide."

the celebration of mass), was labouring under a frightful malady, he suddenly renounced the world, distributed his goods among the poor, and entered a cloister in the thirtieth year of his age. Here he devoted himself to study and religion with the same zeal which he had formerly shown in the pursuit of pleasure. He soon conceived the idea of a crusade to the Barbary states, with the double object of extirpating slavery, and of converting the natives from the errors of Mahommedanism. For this purpose, he travelled through the whole of Western Europe, visiting the courts, conferring with statesmen, generals, and bishops, and exhorting the populace. The complexion of the times rendering all his efforts unavailing, he undertook alone several missionary tours to Cyprus, Armenia, Syria, and Tunis. Whilst zealously preaching Christianity in the last-mentioned region, he was attacked by the mob, stoned, and left for dead on the sea shore, A.D. 1315. Some authors maintain that he was carried off by the crew of a European vessel, resuscitated, and was still living in England in 1332. However this may be, he has bequeathed to the world such an array of goodly volumes, that we ask in wonder how any one immersed throughout life in active enterprise and public negotiations, never residing two consecutive years in the same place, could devote so much time to study? Of his *Ars magna*, or new method of philosophic research, we shall have occasion to speak below. His chemical writings are generally obscure and highly figurative. He first introduced chemical symbols —for what purpose does not appear. He sought the philosopher's stone in the moist way, using distillation, and first drew attention to the volatile products of decomposition. Thus he both led the way to pneumatic chemistry, and contributed to establish the great principle of the indestructibility of matter. He obtained nitric acid by distilling saltpetre with green vitriol —he observed its action upon the metals, and, by adding it to common salt, he obtained an aqua regia capable of dissolving gold. He was acquainted with alcohol, which he called a 'vegetable mercury.' He rectified it over carbonate of potash, and employed it in extracting tinctures. He purified silver by cupellation, prepared the oxide, sulphate, and perhaps the nitric of mercury. He obtained pure carbonate of potash by igniting the cream of tartar, and observed its deliquescence. He invented, or improved the *athanŏr*, a furnace used for slow digestions. Many of the chemical works ascribed to Lully are manifest forgeries. In some of these he is represented as having presented six million pieces of gold to Edward of England, to support his army on a crusade. This story, however, from the circumstances added, cannot apply to either of the three first Edwards. Lully considered the metals as compounds of mercury and sulphur, and believed in transmutation, for which he gives several mystical recipes.

THE METAL MANUFACTURES.

CHAPTER IV.

COPPER.

COPPER is one of the metals which, for engineering purposes, are almost invaluable; arising from its fitness for making vessels and boilers of various kinds. As one of the ingredients in the formation of *brass*, too, as well as of *bronze*, *bell-metal*, and *gun-metal*, its value is observable on every side.

Cornwall is the greatest source of this mineral wealth. When raised to the surface, the ore is separated into different heaps according to its richness, and then the lumps of pure ore are broken into fragments about the size of a hazel-nut. The less pure lumps are broken still smaller and thrown into sieves, which are shaken under the surface of water, whereby the lighter impurities are washed away, and the heavier ore remains. The ore so prepared is sold to the copper companies, by whom it is smelted. These companies are very large concerns; since about ten or twelve of them purchase the whole of the copper-ore throughout the country. Although Cornwall is the place whence the ore is procured, yet South Wales is the district where it is smelted, on account of the cheapness of fuel.

The copper-ore, as brought to the smelting-works, contains generally about eight per cent. of pure copper; the rest being earthy matter, iron, sulphur, arsenic, and other components. By a connected chain of processes, these ingredients are removed one by one, leaving the metallic copper free at last. In the first place, the ore is calcined in a furnace for a space of twelve hours, by which the volatile matters are expelled. The metallic remainder is then let out, in a melted state, from a hole in the side of the furnace into a pit filled with water, where it cools in the form of coarse grains. This granulated metal, consisting of copper, iron, and sulphur, is calcined and melted, over and over again, until it contains eighty or ninety per cent. of pure copper. By a subsequent roasting, the whole of the impurities are finally expelled; and the copper, after various processes of refining and purifying, is brought to the state of cakes or of sheets.

COPPER-SMITHERY.

We may next slightly glance at the modes in which copper is used in manufactures.

The form into which the copper is brought by the smelters is that of square pieces called 'tiles,' measuring nine or ten inches square, and an inch in thickness; and 'cakes,' of a somewhat larger size. These 'tiles' and 'cakes' of copper pass to the copper-mill, of which there are many in various parts of England, those nearest to the metropolis being probably those on the river Wandle, near Mitchman, Merton, and Wandsworth. Here the copper is remelted, and cast into various convenient forms, afterwards to be passed between rollers, if sheet-copper be required. Whatever may be the particular manufacturing arrangements involved, the mode of casting and of rolling or milling may be sufficiently conceived from the details before given respecting iron. Not only is the copper converted into sheets at the copper-mill, but many of the large pieces employed for sugar-pans and other large vessels, receive their first rude form there also, certain facilities being possessed for that purpose. Lastly come the labours of the coppersmith, who works up the rudely-shaped pieces into all the various forms required by the sugar-refiner, the distiller, the brewer, and other manufacturers.

The vessel called a 'sugar-pan' may be taken as a convenient means of illustrating the operations of the copper-manufacture. It consists of a domed vessel, curved and enclosed both at top and bottom, having several apertures for valves, gauges, &c. &c., and a coil of copper-pipe within. The top and bottom, the one convex upwards, and the other convex downwards, are each formed of one piece, which receives its curvature by a very remarkable process. The copper is in the first place cast into a form resembling that of a double convex lens, or spectacle-glass, thickest in the middle, and diminishing gradually towards the edges. This lens is then subjected to the powerful blows of a tilt-hammer, directed more continuously near the centre than near the edges. A little consideration will show that this hammering, while it reduces the thickness of the copper, must make it curl up at the edges, or assume a dished or hollow form: we find that this is the case even when a flat piece of metal is hammered at its centre; and still more does this result ensue when an increased substance is given to the centre. The thickness of the centre is so adjusted as to afford metal enough for the curvature of the vessel; and the hammering is continued till the thickness of the whole is brought nearly uniform. This is a very important process, since the fitness of the vessel for the operations of the sugar-refinery depends on the soundness and perfection of the metal. Sometimes a piece of copper, dished or hollowed in this way, and worth forty guineas if sound, is rendered useless by a flaw in the metal.

The curved piece of copper just spoken of receives its form from the tilt-hammers at the copper-mill, and then passes into the hands of the coppersmith for the subsequent operations. The top and the bottom of the 'sugar pan' receive their form nearly in a similar way; but many smaller pieces have to be added in order to complete the vessel. The side is a portion of a cylinder, made of sheet-copper and riveted at the edge. One of the most noisy operations in a copper-

smith's shop is the hammering which the copper receives in order to render it dense and firm. The piece of copper is supported on an anvil or iron bed, and beaten with hammers in every part, whereby the particles of the metal are brought into a more dense and compact union, and an additional degree of toughness is imparted. The ringing and clanging which this produces in a piece of sheet-copper, perhaps seven or eight feet in diameter, is almost deafening. The name applied to the process is 'planishing;' and where the surface of the copper is very large, the operation has something of the picturesque effect presented by the anchor-smithery; for six or eight men, standing in a circle round the piece of copper, and each wielding a heavy hammer, strike the metal in succession, every part of the surface receiving probably as many as ten or twelve blows. Any one who examines a large copper vessel will see evidences of this 'planishing' process, not only by the hammer marks, but by the density and 'close grain' of the surface.

An important part of the operations is that connected with the riveting or fastening of the joints. This is effected by making one edge overlap the other, and by passing a rivet through them, the point or small end of the rivet being afterwards hammered down. Hence arise three steps in the process—viz., the punching of the holes for the reception of the rivets, the making of the rivets themselves, and the process of riveting. The punching-engine consists principally of a long lever, to the shorter arm of which is attached a punch corresponding to the size of the hole to be made, and generally of a cylindrical shape. The piece of copper is brought to the engine, and placed between the punch and the support beneath, so adjusted as to cause the punch to act on the exact spot where the hole is to be made. A pressure of the lever now causes the punch to descend on the copper, and to cut out a small circular piece corresponding with the required size of the hole. The piece of copper is then shifted onward through a small space, and another hole similarly made; and so on to the required extent.

In the process of riveting, each rivet, which is made at the forge, is passed into the hole bored for its reception, and the point or small end of the rivet is hammered down close to the sheet-copper, so as to clasp it very tightly, having in fact a head or stay within and without. The edge of the copper is then 'caulked,' that is, hammered so as to bring the two surfaces of the joint into very close contact, forming a bond so intimate as to resist the passage of water, air, or steam.

Several of the openings into a sugar-pan, or indeed into other copper vessels used in manufactures, are not simply holes cut in the sheet-metal, but have collars or edges made of cast-metal, whereby the fastening can be effectually secured. These various pieces—the technical names for which need hardly be given here—are cast in sand in the usual manner, and are afterwards turned and finished by other means.

The coil of steam-pipe which occupies the lower part of the interior of a sugar-pan, as a means of heating the sugar to be contained therein, involves operations of a different kind from those hitherto described. This coil usually consists of pipe about three inches in diameter, but much thinner than the same diameter of lead-pipe would be. In order to form it, a strip of copper is taken, as long as may be conveniently obtained, and rather wider than the circumference of the intended pipe. The two edges of this strip are bent upwards, to give the first semblance of a curve; and the piece is then passed through the holes or 'dies' of the tube-drawing machine, by which it is made perfectly cylindrical, with one edge slightly lapping over the other. The joint thus made is secured by a process of soldering or brazing, aided by heat in the usual manner. Soldering or brazing, it may perhaps hardly be necessary to state, depends for its action on the different temperatures at which different metals melt. Thus, to join two pieces of lead, a mixed metal, or 'solder,' is employed, which melts and acts as a cement at a temperature that will not injure the lead. So, in like manner, two pieces of copper are joined or 'brazed' by using a mixed metal partaking of the nature of brass, which remains fluid at a temperature not high enough to injure the copper. A small forge or brazing furnace is employed to heat the metals, and borax is employed to facilitate the fusion of the brass.

Thus far the operations for making a copper-pipe are apparently simple; but the mode of bringing the straight pipe into the form of a coil is very curious. Any attempt to bend a pipe in this manner, so long as the metal is thin and the pipe empty, would be accompanied by a distortion of the sectional area of the pipe, originally circular, and perhaps by fracture. To obviate this, therefore, the interior cavity of the pipe is entirely filled up either with lead or with some composition which will melt and flow at a temperature not likely to injure copper. This being effected, the pipe becomes solid, and may then be bent, without disturbing its shape, by the application of sufficient power. By a simple machine, downward pressure is exerted on the pipe at one part, while upward pressure is exerted on the adjoining parts, whereby the pipe is gradually coiled round into a form nearly resembling that of a common tea-saucer fitted to lie in the bottom of the sugar-pan. By the application of heat on a temporary stove beneath, the interior composition is melted out, and the vacancy restored. The strength of the tube is tested by exposure to steam of high pressure for several days; various minor adjustments are effected, and the coil is inserted in the sugar-pan.

Nearly all the vessels manufactured by the coppersmith are produced by various modifications of the processes here noticed. Cutting, hammering, riveting, planishing, brazing—these are the principal operations performed. If we were to select any other article, and trace it through the successive processes, we should find it, so far as mere description goes, little else than a repetition of the above details. There are, however, some exceptions to this statement, which we may here notice.

In the process of hammering the plates or large surfaces of copper, the hammered surface becomes hardened; and to remedy this, the copper is exposed to a strong heat for a certain time, and then plunged into water, by which an oxide is removed, and the copper softened. For large sheets, this process of annealing is effected on a flat stove, the stove being covered with burning fuel, and the copper laid thereon. A cistern of water is kept near the stove, into which the heated copper is suddenly plunged, as a means of removing the external oxide. For smaller pieces, temporary stoves or fires are adjusted. This process of annealing is not effected in connection with the 'planishing,' but with that hammering whereby the shape of a curved piece of copper is produced. Let us suppose, for instance, that a hemispherical copper cup, a foot in diameter, is to be produced. A circular piece of copper, considerably more than a foot in diameter, is selected, laid on a sort of small convex anvil, and hammered in such a manner as to make the upper surface gradually convex. This is effected by a peculiar action of the hammer, whereby the metal is, as it were, driven from the centre towards the circumference, and gradually curled or turned up. But it happens that, after a certain amount of hammering, the copper becomes so hard as to be in danger of fracture; and it is to remove this hardness that the 'annealing' is effected.

The manufacture of copper-plates for engravers will illustrate the means adopted for producing a level and brilliant polished surface of copper. The copper is in the first instance cut to the required size from a plate of the best and soundest quality; and is then scraped all over with a steel instrument, to remove any slight defects that may exist at the surface. The workman occasionally holds a piece of oiled paper between the window and the plate, whereby a peculiar light falls on the latter, calculated to render the minutest flaws or defects visible. When scraped sufficiently, the plate is taken to an anvil and well hammered, to render it more dense, and also to flatten it. The surface is then well ground with a kind of hard blue stone wetted with water; and finally polished with fine charcoal, by which all the marks from the scraping, hammering, and grinding are removed. When it is considered that the finest lines produced by the graver must be made perfectly distinct and clearly marked, it may well be supposed that the surface is required to be free from scratches and imperfections of every kind.

A GLANCE AT THE STRUCTURE OF THE EARTH.

No. III.—Volcanoes.

In our last paper we treated of the masses of water which lie on the more elevated parts of the earth's crust, in a state of congelation; we will now glance at the effects which the polar opposite of cold has produced, and is producing, in the structure of the earth. It has already been stated in former papers that the deeper we penetrate below the surface, the greater is the heat indicated by the thermometer; and hence some persons conceive that the interior consists of matter in a state of fusion. Whence this intense warmth is derived is a question beset with difficulties. Some maintain that it is the result of violent chemical action going on within, whilst others are of opinion that heat was an original condition of the matter whereof the globe is composed. Seeing that the bodies constituting the globe have a strong affinity for oxygen, and that heat operates to weaken this affinity and to sever the union when it exists, may we not attribute much of the violent action which we observe breaking out in volcanoes, not merely to the contest between caloric and affinity, but to the operation of the laws of affinity itself? When the melted substances come into contact with the atmosphere, or with water, a sudden oxydation will ensue, and we can readily suppose that the process will not take place without very remarkable effects resulting. The bases of all the earths having been found to be metals which have an extraordinary appetency for oxygen, it has been surmised that the interior parts of the earth consist of these metals, and that when the opportunity occurs, they unite themselves with the gas and develope that light and heat which invariably accompany volcanic action. These views were first expounded by Sir Humphrey Davy, and further enlarged upon by Dr. Daubeny, in his work on volcanoes.

"The real question at issue," says Mr Phillips in that masterly exposition of geological science which he wrote for the Encyclopedia Metropolitana, "between the advocates of the principal rival theories is this,—Whether the phenomena of volcanoes seem to imply a process of oxydation or not; if they do, then our acquaintance with bodies that are kindled by the mere contact of water, enables us to explain the manner in which combustion may originate, its continuance being a matter for subsequent consideration, whilst if the facts can be accounted for merely by assuming the presence in the interior of the globe of a mass of melted matter, we should scarcely be disposed to go further for a solution of them." His own theory is, that *salt-water* and afterwards atmospheric air find admittance to cavities in the interior of the earth, where they come in contact with the metals and the earthy or alkaline metalloids combined with sulphur there existing, and he explains how from these various bodies the gaseous and solid matters evolved and ejected from volcanoes are formed. The bodies gradually decompose whenever they come into contact with the air and water, but defended by the crust of the globe, as even a mass of potassium may be by a crust of its own oxide; if kept dry, the chemical action goes on too slowly to produce any striking effects, unless water be present in considerable quantity. But wherever a large mass of water rests upon the solider portion of the globe, the fluid is forced by the pressure through the subjacent strata into the depths beneath, where the chemical processes are stimulated into greater activity, and the more formidable effects of volcanic action are exhibited. It is a remarkable fact in the distribution of volcanoes, and one which to some extent confirms this theory, that they are for the most part near the sea.

At various periods of the earth's history, the latest having elapsed at an indefinite time before our era, it is plain that heat had frequently exerted itself in expelling fused matter from below, through cracks and crevices into the superior strata. This fused matter usually takes the form of granite a rock composed of quartz, felspar, and mica. It has been said that granite is the oldest rock, but in truth it is of every age, for we see it has been poured into the newest deposits. Still there can be no doubt that there were agencies at work, producing granite before any of the stratified rocks were deposited. At every point where this melted substance came into contact with solid matter, a change, more or less great, in the appearance of the latter is observable. An examination of the earth's crust sometimes discloses the singular fact, that a mass of matter which had been forced up through deposited strata is lodged in a melted rock of a later period. These things belong to the earlier history of our globe. Though produced by heat, they were not produced by volcanic action; at least, by what is usually understood by that term. By volcanoes, we mean those orifices on the surface of the earth by which the internal heat is exhibited in its violent effects. The usual concomitants of volcanic action, are the evolution of gas, smoke, and ignited substances, the ejection of stony fragments and ashes, and noise produced by the phenomena previously noticed. The matter which issues from a volcano in a melted stream and afterwards solidifies, is termed lava; the loose iron-clay, or sand, in which fragments are embedded, has received the name of puzzolano.

When Mr. Scrope stood on a point of rock which commanded a view of the inside of the crater of Stromboli, he saw it filled with a mass of melted matter, which alternately rose and fell; and when at its height, large bubbles formed on the surface and burst with a loud explosion, which sent upwards a shower of liquid lava that fell in the shape of scoriæ. This spectacle must have been one of exciting interest. When the liquid substances are supplied from below at a rapid rate, the pan gets full and soon overflows, sending a stream over its brim as long as the fluid is forced so high.

Geologists inform us that there are good grounds for assuming that earthquakes are connected with volcanoes in a more or less intimate manner. Earthquakes are usually noticed to precede or accompany outbursts of matter, and to extend over large tracts of ground, but to cease when the ejection has carried off the loose substances. In 1797, the volcano of Pasto, in South America, had thrown out a dense mass of smoke, which suddenly ceased to be emitted. It was afterwards ascertained that at the same time a tremendous earthquake occurred sixty-five leagues further south, and the town of Riobomba was destroyed.

The principal recent volcanoes of the world are the following:—*Europe:* Vesuvius, on the east of the bay of Naples. Its most destructive eruption was in 79 A.D., when the cities of Stabiæ, Pompeii, and Herculaneum were buried beneath the ejected matter. Since that period there have been many memorable outbursts, and the quantity of matter forced through its orifices is enormous. In 1737, thirty-three millions of cubic feet were thrown out, and in 1794, forty-six millions of cubic feet. The lava on the latter occasion advanced with a front of 1127 feet, no less than 362 feet into the sea. Not far distant from the town of Puzzuoli is a crater called Solfatorra, and in the vicinity a mountain called the Monte Nuovo was thrown up, in the sixteenth century, 8000 feet in circumference, and 413 in perpendicular height. That internal heat is still at work here, is shown by the fact, that the sand at the foot of the mountain, a little below the surface of the sea, is of a high temperature. The temple of Serapis at Puzzuoli exhibits a very singular phenomenon, which is evidence of the fluctuations in the level of the land at that locality. The pillars of the temple have been perforated to the height of twelve feet from the ground by the marine animal *pholas.* Now, it is evident, that when the building was erected, it must have been at some height above the sea—the borings of the pholades show that it was at some time submerged—and now it is seen standing once more on dry land. There are many other spots in the vicinity of Naples, such as the Grotto del Cane and the islands of Procida and Ischia, which have all the appearances of igneous action. But, indeed, the whole space between latitude 40° and 41°, in the Italian peninsula, is full of evidence of recent volcanic operations. The Lipari islands have been entirely formed by these means. In the island of Sicily we

have the celebrated Ætna rising to a height of 10,000 feet, with a circumference of ninety miles, and almost entirely produced by igneous agency. In the neighbourhood of the same island, so lately as 1831, a volcano broke out at a spot in the ocean where nothing of the sort had been previously known. A little hillock, elevated a few feet above the sea, out of which a column of white smoke or steam issued, was first perceived by a vessel sailing in the Mediterranean. The hillock gradually increased in size, until it attained a height of 107 feet, with a circumference of more than three thousand. In the ensuing winter, the waves washed the loosely accumulated materials nearly altogether away, and now only a shoal with a patch of rock in the centre remains, to show where this curious phenomenon occurred. In the Grecian Archipelago, there are three islands which are believed to be the ruins of a vast crater. In Iceland, volcanic phenomena are frequent. The last eruption of Hecla occurred in 1766. In 1783, an enormous quantity of liquid matter was poured out of two contiguous volcanoes in three streams, which afterwards united and covered 1200 square miles. In the same year, a new island was produced, a mile in circumference, which consisted of high cliffs. It lasted but a day, and then sunk beneath the water, where there is now scarcely a reef. In the island of Jan Mayen, off the Greenland coast, there is a volcano, which, when visited in 1817, had a crater 2000 feet in diameter, and 500 in depth.

There are many places in Europe which have all the appearance of having been at some period the theatres of volcanic action, which has now ceased. There are indications of volcanoes in Spain, Portugal, and France. In the province of Auvergne, situated in the centre of the last-named kingdom, there is a mountainous region which is much visited for its peculiar scenery created by igneous agency. Nearly twenty craters have been counted in that district, and there are several mountains formed by ejected lava and scoriæ, the highest of which is the Puy de Dome. In Germany, the Eifel country on the banks of the Rhine is well known to the geologising tourist. Dr. Hibbert of Edinburgh visited it a few years ago, and published an excellent account of this interesting district, which is for the most part an aggregation of volcanic sand, turf, and scoriæ. Some of the craters have become filled with little lakes, the most remarkable of which is the pretty river of Laach near Andernach. We are told that, in spite of the silence of history, it is difficult not to believe that eruptions have taken place here within a comparatively recent period. A little lower down the Rhine is that picturesque group of hills called the Seven Mountains, so famous in song and story, of which the Drachenfels is the best known by name. They are chiefly composed of basalt thrown up since the brown coal deposits accumulated in the tertiary strata.

In the vast continent of *Asia*, there are many striking phenomena connected with volcanic action. In the interior, Humboldt calculates that the country which is, or has been, the scene of modern eruptions, is 2500 leagues in extent. Some of the islands of the Indian Archipelago are occupied by volcanoes. The higher islands of the Pacific Ocean are all volcanic, and perhaps the bases of the coral reefs and coral islands are also altogether volcanic. A crater in the island of Owhyee is in a state of ceaseless activity, and another volcanic mountain, now quiet, attains a height of more than 16,000 feet.

As to *Africa*, we have no trustworthy account of there being any volcanoes on that Continent; but a great many of the islands off the coast are undoubtedly of igneous origin. The islands of Ascension, Mauritius, and Bourbon, are all volcanic, the least one having very active vents, which for some years past have thrown out two lava streams per annum. In the island of Teneriffe too we are told that we may see specimens of every variety of volcanic product that is elsewhere to be found.

The smaller islands of the West Indian Archipelago, are chiefly composed of volcanic materials, and some contain active vents, such as St. Vincent, and St. Lucia.

In *America* the most northerly volcanoes are three active ones in California. In Mexico there are numberless hills that have upon them active or extinct craters. It is an interesting fact that in the parallel of the capital there are five burning mountains, which from their standing in a line, would seem to be derived from causes operating through an immense split running east and west. The veteran Humboldt spent some time in investigating the volcanic phenomena of this district. He is of opinion that the mountain Jorullo, not far short of two thousand feet in height, was lifted at once from the interior of the earth to its present position in 1759, and his opinion is confirmed by the tradition of the Indians. If this be the fact, how mighty must the power have been, that wrought an effect like this, and at the same time elevated a plain of three or four square miles, a considerable height above its ancient level. In other parts of South America there are several lines of volcanoes; in Chili alone, sixteen burning mountains are enumerated.

As to the matter ejected from volcanoes, observers tell us that a vast quantity of aeriform fluid is evolved. Steam is produced by some subterraneous boiler, and sent out into the atmosphere with a violent rush. Sir Humphrey Davy noticed the marked distinction between the steam emitted from one crater of Mt. Vesuvius and the smoke that issued from another. In the day-time the steam was perfectly white, and in a morning and evening displayed by reflection beautiful tints of red and orange, whilst the smoke formed intensely black clouds, and at the moment of expulsion in the night time it was luminous in a high degree. Gases also, are disengaged, being principally muriatic acid, sulphuretted hydrogen, sulphurous acid, carbonic acid, and nitrogen; petroleum, boracic acid, muriate of ammonia, and common salt, are frequently found condensed round a volcano, having issued from its orifices in a state of vapour. The principal solid substance that a volcano sends out of its bowels is lava, a composition of various matters, which have evidently been altogether altered from their original constitution by the operation of heat. It issues a half-fluid substance with a temperature sufficiently high to melt glass and silver, but it soon cools on the surface although the interior will retain its fluidity for some time. Upon analysing specimens of lavas from mount Ætna, they were found to consist of about one-half silicious earth, the remainder being alumina, lime, soda, and oxide of iron, the first substance being about a fifth of the whole mass. Mineralogists call the substance felspathic, the constituents of felspar approaching those of lava. Upon breaking a piece of lava, various crystallised and uncrystallised substances are found embedded, such as olivine, mica, hornblende, augite and titaniferous iron. Matter extremely like lava in constitution is often sent out in loose fragments, but their structure is more cellular, and is sometimes fibrous. There is a rock called trachyte, which is observed in large quantites in all volcanic districts. It is plainly an ignigenous product consisting of compact felspar with crystals of glassy felspar embedded, often with crystals of augite and hornblende. There is reason to believe that modern lava is nothing more in many instances than trachyte, which has undergone a second time the process of fusion. Trachyte, on being analysed is found to bear so strong a resemblance to granite, that one geologist terms it granitoid lava; the distinction is, that quartz is present in one, and absent in the other.

THE INVENTION OF THE TELESCOPE.

The telescope, as every person knows, is an optical instrument for viewing objects at a distance. Its name is compounded of two Greek words, *tēlĕ*, which signifies *at a distance*, and *scŏpĕin, to view.* By means of telescopes remote objects are represented as if they were near, small apparent magnitudes are enlarged; apparently confused objects are rendered distinct; and the invisible and obscure parts of very distant scenes are ren-

dered perceptible and clear to the organs of vision. The telescope is justly considered a grand and noble instrument. It is indeed truly surprising, that it should be in the power of man to invent and construct an instrument, by which objects too remote for the unassisted eye to distinguish, should be brought within the range of distinct vision, as if they were only a few yards from our eye; and that thousands of august objects in the heavens, which had been concealed from mortals for numerous ages, should be brought within the limits of our contemplation, and be as distinctly perceived, as if we had been transported many millions of miles from the space we occupy through the celestial regions.

The persons who constructed the first telescopes, and the exact period when they were first invented, are involved in some degree of obscurity. It does not certainly appear that such instruments were known to the ancients, although we ought not to be perfectly decisive on this point. The cabinets of the curious contain some very ancient gems of admirable workmanship, the figures in which are so small, that they appear beautiful through a magnifying glass, but altogether confused and indistinct to the naked eye; and, therefore, it may be asked, if they cannot be *viewed*, how could they be wrought without the assistance of glasses? And, as some of the ancients have declared, that the moon has a form like that of the earth, and has plains, hills, and valleys in it—how could they know this, unless by mere conjecture, without the use of a telescope? And how could they have known that the *Milky Way* is formed by the combined rays of an infinite number of small stars? For Ovid states, in reference to this zone—"its ground-work is of stars." Plutarch speaks of mathematical instruments which Archimedes made use of, *to manifest to the eye the largeness of the sun*, which might possibly refer to an instrument partaking of the nature of a telescope. But whatever notions the ancients may have possessed of the telescope, or other optical glasses, it is quite evident that they never had telescopes of such size and power as those we now possess; and that no discoveries in the heavens, such as are now brought to light, were made by any of the ancient astronomers, otherwise some allusions to them must have been found in their writings.

Among the moderns, the illustrious Friar Bacon seems to have acquired some rude ideas respecting the construction of telescopes. "Lenses and specula," says he, "may be so figured, that one object may be multiplied into many—that those which are situated at a great distance, may be made to appear very near—that those which are small, may be made to appear very large—and those which are obscure very plain; and we can make stars to appear wherever we will." From these expressions, it appears highly probable, that this philosopher was acquainted with the general principle both of telescopes and microscopes; and that he may have constructed telescopes of small magnifying power for his own observation and amusement, although they never came into general use. He was a man of extensive learning, and made so rapid a progress in the sciences, when attending the University of Paris, that he was esteemed the glory of that seat of learning. He prosecuted his favourite study of experimental philosophy with unremitting ardour; and, in this pursuit, in the course of twenty years, he expended no less than £2000 in experiments, instruments, and in procuring scarce books. In consequence of such extraordinary talents, and such astonishing progress in the sciences, in that ignorant age he was represented, by the envy of his illiterate fraternity, as having dealings with the devil; and, under this pretence he was restrained from reading lectures, and, at length, in 1278, when 64 years of age, he was imprisoned in his cell, where he remained in confinement for ten years. He shone like a bright star in a dark hemisphere—the glory of our country—and died at Oxford, in the year 1296, in the 80th year of his age. "Friar Bacon," says the Rev. Mr Jones, "may be considered as the first of English philosophers; his profound skill in mechanics, optics, astronomy, and chemistry, would make an honourable figure in the present age. But he is entitled to further praise, as he made all his studies subservient to theology, and directed all his writings, as much as would be, to the glory of God. He had the highest regard for the Sacred Scriptures, and was persuaded they contain the principles of all true science."

The next person who was supposed to have acquired a knowledge of telescopes was Joannes Baptista Porta of Naples, who flourished in the sixteenth century. He discovered the *Camera Obscura*—the knowledge of which might naturally have led to the invention of the telescope; but it does not appear that he ever constructed such an instrument. Des Cartes considers James Metius, a Dutchman, as the first constructor of a telescope; and says, that as he was amusing himself with making mirrors and burning-glasses, he casually thought of looking through two of his lenses at a time, and that distant objects appeared very large and distinct. Others say that this great discovery was first made by John Lippersheim, a maker of spectacles at Middleburgh, or rather by his children, who were diverting themselves with looking through two glasses at a time, and placing them at different distances from each other. But Borellus, who wrote a book "on the invention of the telescope," gives this honour to Zacharias Jansen, another spectacle-maker in the same town, who, he says, made the first telescope in 1590. Jansen was a diligent inquirer into nature; and, being engaged in such pursuits, he was trying what uses could be made of lenses for those purposes, when he fortunately hit upon the construction. Having found the arrangement of glasses which produced the effect desired, he enclosed them in a tube, and ran with his instrument to Prince Maurice, who, immediately conceiving it might be of use to him in his wars, directed the author to keep it a secret. Such are the rude conceptions and selfish views of princely *warriors*, who would apply every invention in their power for the destruction of mankind. But the telescope was soon destined to more noble and honourable achievements. Jansen, it is said, directed his instrument to celestial objects, and distinctly saw the spots on the surface of the moon, and discovered many new stars, particularly seven pretty considerable ones in the Great Bear. His son Joannes is said to have noted the lucid circle near the lower part of the moon, now named *Tycho*, from whence several bright rays seem to dart in different directions. In viewing Jupiter, he perceived two, sometimes three, and at the most four, small stars, a little above or below him, and thought that they performed revolutions around him. This was probably the first observation of the satellites of Jupiter, though the person who made it was not aware of the importance of his discovery.

It is not improbable that different persons about Middleburgh hit upon the invention in different modes about the same time. Lippersheim seems to have made his first rude telescope by adjusting two glasses on a board, and supporting them on brass circles. Other workmen, particularly Metius and Jansen, in emulation of each other, seem to have made use of that discovery, and by the new form they gave it, made all the honours of it their own. One of them, considering the effects of light as injurious to distinctness, placed the glasses in a tube blackened within. The other, still more cautious, placed the same glasses within tubes, capable of sliding one in another, both to vary the prospects by lengthening the instrument, according to the pleasure of the observer, and to render it portable and commodious. Thus it is probable that different persons had a share in the invention, and jointly contributed to its improvement. At any rate, it is undoubtedly to the Dutch that we owe the original invention. The first telescope made by Jansen did not exceed 15 or 16 inches in length, and therefore its magnifying power could not have been very great.

The famous Galileo has frequently been supposed to have been the inventor of the telescope; but he acknowledges that he had not the honour of being the original inventor, having first learned from a German that such an instrument had already been made, although, from his own account, it appears that he had actually reinvented this instrument. The following is the account, in his own words, of the circumstances which led him to construct a telescope:—"Nearly ten months ago," [namely, in April, or May, 1609,] "it was reported that a certain Dutchman had made a perspective, through which many distant objects appeared distinct as if they were near; several effects of this wonderful instrument were reported, which some believed and others denied; but having it confirmed to me a few days after by a letter from the noble John Badoveric, at Paris, I applied myself to consider the reason of it, and by what means I might contrive a similar instrument, which I afterwards attained to by the doctrine of refractions. And first I prepared a leaden tube, to whose extremities I fitted two spectacle glasses, both of them plain on one side, and on the other side, one of them was spherically convex, and the other concave. Then applying my eye to the concave, I saw objects appear pretty large, and pretty near me. They appeared three times nearer, and nine times larger in surface than to the naked eye; and, soon after, I made another, which

represented objects above 60 times larger, and 8 times nearer; and, at last, having spared no labour nor expense, I made an instrument so excellent as to show things almost a thousand times larger, and above 30 times nearer than to the naked eye." In another part of his writings, Galileo informs us that, "He was at Venice when he heard of Prince Maurice's instrument, but nothing of its construction; that the first night after he returned to Padua, he solved the problem, and made his instrument the next day, and soon after presented it to the Doge at Venice; who, to do him honour for his grand invention, gave him the Ducal letters which settled him for life in his lectureship at Padua; and the Republic, on the 25th of August, in the same year (1610,) more than tripled his salary as professor."

The following is the account which this philosopher gives of the process of reasoning which led him to the constructing of a telescope:—"I argued in the following manner. The contrivance consists either of one glass or of more—one is not sufficient, since it must be either convex, concave, or plane—the last does not produce any sensible alteration in objects, the concave diminishes them;—it is true that the convex magnifies, but it renders them confused and indistinct; consequently one glass is insufficient to produce the desired effect. Proceeding to consider two glasses, and bearing in mind that the plane-glass causes no change, I determined that the instrument could not consist of the combination of a plane glass with either of the other two; I therefore applied myself to make experiments on combinations of the two other kinds and thus obtained that of which I was in search." If the true inventor is the one who makes the discovery by reasoning and reflection—by tracing facts and principles to their consequences, and by applying his invention to important purposes—then Galileo may be considered as the real inventor of the telescope. No sooner had he constructed this instrument—before he had seen any similar one—than he directed his tube to the celestial regions, and his unwearied diligence and ardour were soon rewarded by a series of new and splendid discoveries. He descried the four satellites of Jupiter, and marked the periods of their revolutions; he discovered the phases of Venus, and thus was enabled to produce a new proof of the Copernican system, and to remove an objection that had been brought against it. He traced on the lunar orb a resemblance to the structure of the earth, and plainly perceived the outlines of mountains and vales casting their shadows over different parts of its surface. He observed that, when Mars was in quadrature, his figure varied slightly from a perfect circle; and that Saturn consisted of a triple body, having a small globe on each side—which deception was owing to the imperfect power of his telescope, which was insufficient to show him that the phenomenon was in reality a *ring*. In viewing the sun, he discovered large dark spots on the surface of that luminary, by which he ascertained that that mighty orb performed a revolution round its axis. He brought to view multitudes of stars imperceptible to the naked eye; and ascertained that those nebulous appearances in the heavens, which constitute the Milky Way, consist of a vast collection of minute stars, too closely compacted together to produce impressions individually on our unassisted vision.

Having briefly stated the circumstances which led Galileo to the construction of a telescope, and the discoveries he made with that instrument, we may now shortly advert to the reception his discoveries met with from the scientific and literary world. The results of his observations were given to the world in a small work entitled "*Nuncius Sidereus*"—"News from the starry regions," which produced an extraordinary sensation among the learned. These discoveries soon spread throughout Europe, and were incessantly talked of, and were the cause of much speculation and debate among the circles of philosophers. Many doubted; many positively refused to believe so novel and unlooked for announcements, because they ran counter to the philosophy of Aristotle, and all the preconceived notions which then prevailed in the learned world. It is curious, and it may be instructive to consider to what a length of absurdity prejudice and ignorance carried many of those who made pretensions to learning and science. Some tried to reason against the facts alleged to be discovered; others contented themselves, and endeavoured to satisfy others, with the simple *assertion*, that such things were not, and *could not possibly be;* and the manner in which they supported themselves in their incredulity was truly ridiculous. "O my dear Kepler," says Galileo, in a letter to that astronomer, "how I wish we could have one hearty laugh together. Here, at Padua, is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and the planets through my glass, which *he pertinaciously refuses to do*, lest his opinions should be overturned. Why are you not here? what shouts of laughter should we have at this glorious folly!—and to hear the professor of philosophy at Pisa, labouring with the Grand Duke with logical arguments, as if with magical incantations, to charm the new planets out of the sky." Another opponent of Galileo, one Christmann, says in a book he published:—"We are not to think that Jupiter has four satellites given him by nature, in order, by revolving round him, to immortalize the Medici, who first had notice of the observation. These are *the dreams of idle men*, who love ludicrous ideas better than our laborious and industrious correction of the heavens. Nature abhors so horrible a chaos, and, to the truly wise, such vanity is detestable." One Martin Horky, a would-be philosopher, declared to Kepler, "I will never concede his four new planets to that Italian from Padua, though I should die first;" and, he followed up this declaration by publishing a book against Galileo, in which he examines four principal questions respecting the alleged planets:—1st, Whether they exist? 2d, What they are? 3d, What they are like? 4th, Why they are? The first question is soon disposed of, by declaring positively that he has examined the heavens with Galileo's own glass, and that no such thing as a satellite about Jupiter exists. To the second, he declares solemnly that he does not more surely know that he has a soul in his body, than that reflected rays are the sole cause of Galileo's erroneous observations. In regard to the third question, he says, that these planets are like the smallest fly compared to an elephant; and, finally, concludes on the fourth, that the only use of them is to gratify Galileo's "thirst of gold," and to afford himself a subject of discussion. Kepler, in a letter to Galileo, when alluding to Horky, says, "He begged so hard to be forgiven, that I have taken him again into favour, upon this preliminary condition—that I am to show him Jupiter's satellites, AND HE IS TO SEE THEM, and own that they are there."

The following is a specimen of the reasoning of certain pretended philosophers of that age against the discoveries of Galileo. Sizzi, a Florentine astronomer, reasons in this strain:—"There are seven windows given to animals in the domicile of the head, through which the air is admitted to the rest of the tabernacle of the body, to enlighten, to warm, and to nourish it; two nostrils, two eyes, two ears, and a mouth; so in the heavens, or the great world, there are two favourable stars, two unpropitious, two luminaries, and Mercury alone undecided and indifferent. From which, and many other similar phenomena in nature, such as the seven metals, &c., we gather that the number of planets is *necessarily seven*. Moreover, the satellites are invisible to the naked eye, and therefore can exert no influence on the earth, and therefore would be useless, *and therefore do not exist*. Besides, as well the Jews as other ancient nations, have adopted the division of the week into seven days, and have named them from the seven planets. Now, if we increase the number of the planets, the whole system falls to the ground." The opinions which then prevailed in regard to Galileo's observations on the moon, were such as the following:—Some thought that the dark shades on the moon's surface arose from the interposition of opaque bodies floating between her and the sun, which prevent his light from reaching those parts; others imagined that, on account of her vicinity to the earth, she was partly tainted with the imperfection of our terrestrial and elementary nature, and was not of that entirely pure and refined substance of which the more remote heavens consist; and a third party looked on her as a vast mirror, and maintained that the dark parts of her surface were the reflected images of our earthly forests and mountains.

Such learned nonsense is a disgrace to our species, and to the rational faculties with which man is endowed; and exhibits, in a most ludicrous manner, the imbecility and prejudice of those who made bold pretensions to philosophy and erudition. The statement of such facts, however, may be instructive, if they tend to guard us against those prejudices and preconceived opinions, which prevent the mind from the cordial reception of truth, and from the admission of improvements in society which run counter to long-established customs. For the same principles and prejudices, though in a different form, still operate in society, and retard the improvement of the social state, the march of science, and the progress of Christianity. How ridiculous is it for a man,

calling himself a philosopher, to be afraid to look through a glass to an existing object in the heavens, lest it should endanger his previous opinions! And how foolish is it to resist any improvement and reformation in society, because it does not exactly accord with existing opinions, and with "the wisdom of our ancestors!" Were all the foolish and untenable notions, so frequently imbibed in early life, completely eradicated, and the mind prepared for the reception of important and demonstrable truths, a broad foundation would be laid for the progress of both science and religion, and for the universal diffusion of useful knowledge among all nations, and among every rank in society.

It is not a little surprising that Galileo should have first hit on that construction of a telescope which goes by his name, and which was formed with a *concave* glass next the eye. This construction of a telescope is more difficult to be understood in theory, than one which is composed solely of convex glasses; and its field of view is comparatively very small, so that it is almost useless when attempted to be made of a great length. In the present day, we cannot help wondering that Galileo and other astronomers should have made such discoveries as they did with such an instrument, the use of which must have required a great deal of patience and address. Galileo's best telescope, which he constructed "with great trouble and expense," magnified the diameters of objects only thirty-three times, but its length is not stated, which would depend upon the focal distance of the concave eye-glass. If the eye-glass was two inches focus, the length of the instrument would be five feet four inches; if it was only one inch, the length would be two feet eight inches, which is the least we can allow to it, the object-glass being thirty-three inches focus, and the eye-glass placed an inch within this focus. With this telescope, Galileo discovered the satellites of Jupiter, the crescent of Venus, and the other celestial objects to which we have already alluded. The telescopes made in Holland, are supposed to have been constructed solely of convex glasses, on the principle of the astronomical telescope; and if so, Galileo's telescope was in reality a new invention.

Certain other claimants of the invention of the telescope have appeared besides those already mentioned. Francis Fontana in his "*Celestial Observations*," says that he was assured by a Mr Hardy, advocate of the parliament of Paris, a person of great learning and undoubted integrity, that, on the death of his father, there was found among his things an old tube, by which distant objects were distinctly seen, and that it was of a date long prior to the telescope lately invented, and had been kept by him as a secret. Mr Leonhard Digges, a gentleman who lived near Bristol in the seventeenth century, and was possessed of great and various knowledge, positively asserts in his "*Stratoticus*," and in another work, that his father, a military gentleman, had an instrument which he used in the field, by which he could bring distant objects near, and could know a man at the distance of three miles. Mr Thomas Digges in the preface to his "*Pantometria*," published in 1591, about eighteen years before Galileo made his first telescope, declares, "My father by his continual painful practices, assisted by demonstrations mathematical, was able, and sundry times hath by proportional glasses, duly situate in convenient angles, not only discovered things far off, read letters, discovered pieces of money, with the very coin and superscription thereof, cast by some of his friends of purpose, upon downs in open fields, but also seven miles off, declared what hath been done that instant in private places. He hath also sundry times, by the sunbeams fired powder, and discharged ordnance half a mile and more distant, and many other matters far more strange and rare, of which there are yet living divers witnesses."

It is by no means unlikely that persons accustomed to reflection, and imbued with a certain degree of curiosity, when handling spectacle glasses, and amusing themselves with their magnifying powers, and other properties, might sometimes hit upon the construction of a telescope; as it only requires two lenses of different focal distances, to be held at a certain distance from each other, in order to show distant objects magnified. Nay, even one lens of a long focal distance is sufficient to constitute a telescope of a moderate magnifying power, and I have one in my possession with which I can perceive what o'clock it is on a dial-plate more than two miles distant. But such instruments, when they happened to be constructed accidentally, appear to have been kept as secrets, and confined to the cabinets of the curious, so that they never came into general use; and as their magnifying power would likely be comparatively small, the appearance of the heavenly bodies would not be much enlarged by such instruments—nor is it likely they would be often directed to the heavens. On the whole, therefore, we may conclude, that the period when instruments of this description came into general use, and were applied to useful purposes, was when Galileo constructed his first telescope.

For a period of more than forty years after Galileo constructed his best telescope, it does not appear that telescopes were much more improved as to magnifying power, than they were in 1610, when that philosopher discovered the satellites of Jupiter, and the triple appearance of Saturn. The first person who made considerable improvements as to the length and powers of these instruments, was the celebrated Huygens. He tells us in his *Dioptrics*, that "Galileo could not discover the true shape of Saturn, nor any one after him for many years. For, though they had lengthened their tubes very much, yet they improved their power and efficacy but very little. As for myself, I undertook this business with a better prospect of success, and after I had acquired a thorough knowledge of the laws of refraction, and had made my own object-glasses and telescopes above twenty feet long, with these I discovered the true forms of Saturn and the true cause of them to be a ring surrounding his body. I also discovered a satellite revolving about him in sixteen days." He also tells us that "he had made a discovery for using a long telescopic glass, without the trouble of using long and weighty tubes, and indeed without any tubes at all, it being as easy now to observe with an object glass of 100 or 200 feet focal distance, as it was before with a tube of ten feet." These were called *Aerial* telescopes, but they are now entirely superseded by achromatic and reflecting telescopes. About the year 1672, Sir Isaac Newton invented that form of a reflecting telescope which bears his name, but the invention lay dormant for half a century, till Mr Hadley, in 1723, constructed a large Newtonian, $62\frac{1}{2}$ inches focal distance, which magnified from 190 to 230 times, and about sixty-six years afterwards, Herschel constructed his large forty feet reflector, the largest instrument of the kind that has yet been erected. In 1759, Dollond invented the achromatic telescope, since which period this construction has almost superseded every other kind of refracting telescope, and has come into general use both for viewing land objects and for celestial observations; and telescopes of this kind have been constructed nearly twenty feet long, with the object-glass fifteen and eighteen inches in diameter. The largest telescope that has ever been projected, is that of the Earl of Rosse, the speculum for which was cast in April, 1842. It is six feet diameter, and is to be formed into a telescope fifty feet focal length. It will have a reflecting surface of 4071 square inches, or more than double that of Herschel's forty feet reflector, and it is hoped that some new discoveries will be made by it in the heavens.

NEW APPARATUS FOR EXTRACTING THE COLOURING MATTER OF DYEWOODS.

(From the Bulletin de la Société Industrielle de Mullhouse.)

In order to make decoctions of logwood, the usual method is to put a quantity of shavings of that wood into a boiler in immediate contact with the fire, together with a quantity of water, sufficient to cover the wood completely, so that after boiling for some hours the wood may be quite covered. The operation is renewed twice with the same liquor, and after three successive boilings, the decoctions are mixed together and evaporated to the degree required.

This operation is attended with several disadvantages. Shavings only can be employed, for if the logwood is reduced to powder, it absorbs so much water that a great quantity of liquid is lost, and the shavings being rather thick, the water cannot readily penetrate, for which reason the time of boiling is very much prolonged.

Notwithstanding these three long boilings, if the same wood be boiled a fourth time, a liquid pretty well coloured is obtained; which clearly shows that all the colouring matter has not been extracted.

Besides this, when decoctions of logwood are required in large quantities, very large vessels and extensive premises are necessary, as well as several furnaces, in order to produce a sufficient quantity, for the wood, when in shavings, is very bulky without being heavy,

and large boilers are required for making a decoction from 50 lbs. of shavings, with the necessary quantity of water. Several boilers must therefore be employed, otherwise the fire must be kept up day and night.

I will here describe, *en passant*, for the benefit of those persons who have not many furnaces, but who have a steam-pipe at command, a method which I have employed for some time to make decoctions in great quantities, and which I think I can recommend in this instance.

A large high narrow vat, capable of containing about from 100 to 150 lbs. of wood shavings, is mounted upon a stand or framing, and furnished with a cock below, in order to draw off the liquor. At a short distance above the cock, inside the vat, a false bottom or diaphragm, pierced with holes very close to each other, is fixed, in order to leave a space at the bottom to prevent the wood from clogging up the cock, and stopping the flow of the liquor. A steam-pipe, about one-third of an inch in diameter, is carried to the bottom of the vat, which is filled with shavings. It is covered with a cloth and a cover, which is weighted, in order to prevent the steam from issuing out in too great abundance. The shavings must not be heaped up more than in the common boilers. In this state, steam is allowed to flow in for an hour at least, until it escapes out in moderate quantities at the top. During this time the wood swells and becomes penetrated by the steam; then when the vat is filled with water, it will be sufficient to heat it to the boiling point, in order to obtain, the first time, a strong decoction. The vat is afterwards filled twice in succession, and made to boil as usual; and in the same space of time, with less labour, a much larger quantity of decoction is obtained, and much more colouring matter extracted.

By the two methods just mentioned, considerable time is required for each operation, and the wood is not entirely exhausted of colouring matter; but with M. Meissonnier's apparatus much more advantageous results are attained.

This improved apparatus consists of a copper boiler of about a foot and a half in width, and about two feet in depth. At a short distance from the bottom of the boiler is a false bottom, pierced with a multitude of holes, which sustains the wood in the water, and leaves an empty space for the boiling liquor. Into the boiler powdered wood is thrown, and it is covered first with strong wire-work, and then with a copper-plate, pierced with small holes, which cover is held firmly down upon the edges of the boiler by any suitable means. At the side of the boiler is a small lift and force-pump, simply constructed, which draws the boiling water from any suitable vessel, and forces it through a pipe into the empty space at the bottom of the boiler. The water after passing through the wood and the pierced cover of the boiler, is run off into any suitable receiver.

In our manufactory, at the side of the pump is a boiler, heated with a coal-fire, capable of containing 450 quarts of water which is to be boiled for each operation. After filling it, and lighting the fire, the other boiler is filled with powdered logwood, spread as evenly as possible, until it contains from 84 to 90 pounds of wood. The water having arrived at the boiling point is then forced into the space at the bottom of the vessel containing the dyewood, and driven up through the wood. In this manner, in two hours, the 450 quarts pass through and extract all the colouring matter from the dyewood.

The liquor which has passed through the wood is divided into three distinct portions,—in this manner: a first portion of the decoction may be $3\frac{1}{2}°$ Beaume; a second, $1\frac{1}{2}°$; a third, $\frac{1}{2}°$; and lastly, a fourth portion of liquid very slightly coloured, which may be mixed with the water for the next operation. In this manner the most advantageous results are secured, as three decoctions of different degrees of strength are obtained at one working, without evaporation.

When a second operation is not commenced immediately, the waste heat of the furnace is employed to concentrate the liquor.

I will compare the advantages of this apparatus with that which we were obliged previously to use.

Thus, in a boiler heated by fire, 140 pounds of shavings and 80 quarts of water were put, and the liquor was boiled for four hours; this was renewed three times. For 40 pounds of logwood, it was, therefore, necessary to boil 240 quarts of water for twelve hours. I double these quantities the better to compare them with those produced by the new apparatus. Thus, by the old method, for 80 pounds of wood it was necessary to boil 480 quarts of water during twenty-four hours.

By this novel method, when from 84 to 90 pounds of wood are operated upon, two hours are necessary for heating the 450 quarts of water, and two hours for pumping it through the wood. Therefore, for 84 pounds of wood, it will be necessary to heat 450 quarts of water for four hours, effecting an economy of fuel for twenty hours' consumption. Besides this, the colouring matter is better extracted, and a great economy of labour is effected, as one man can effect two operations per diem.

Several precautions are necessary, in fact indispensable, to ensure complete success; for instance, the wood must be very evenly spread, in order that the resistance offered to the water may be equal throughout: and for this purpose, the wood must be put into the vessel in small quantities at a time. A very important point is, to have the wood ground or rasped of a uniform size, without fine dust, as the particles of this latter are apt to adhere together, and offer great resistance to the water at certain parts; thus preventing the colouring matter from being extracted therefrom. I have found that the wood spreads much better by previously wetting it.

For some other woods, such as Lima and Pernambouc woods, and other red dyewoods, 600 quarts of water, instead of 450, must be employed, as the colouring matter is not so easily extracted. Quercitron cannot be operated upon, as it is too fine a powder. Cochineal does not succeed, as it swells so much on coming in contact with boiling water that, in an experiment I made, I thought it would have burst the boiler.

This apparatus is, however, very advantageous for the woods above-mentioned, if the directions given are carefully followed.

MURRAY'S PATENT BRICK-MAKING MACHINE.

The economical manufacture of bricks by machinery, has hitherto been generally considered as extremely problematical, and with good reason, when we consider the host of abortive schemes which have been tried for effecting this purpose and as often given up; some on the score of expense, and the complication of parts which the process necessarily involved, others from the fact that the ordinary method of manufacture by hand was more expeditious.

Mr Murray's machine is one of the latest inventions of the kind, and from its having been sometime in actual operation at Garnkirk in the making of fire-bricks, we augur well of its ultimate usefulness. Contrary to most arrangements of this nature, the necessary pressure for forming the bricks, is given by a hydrostatic press, which compresses the clay into cast-iron moulds.

Upon the moving table of a hydrostatic press, are attached a series of cast-iron dies or stamps (in the present instance they are twenty in number) of the exact size of the intended bricks. Above this table is suspended, by means of counter-weights, a cast-iron mould frame, corresponding with the dies fixed to the table, and and is guided in its vertical motions by the pillars of the press.

The clay which is moulded by this machine requires no other preparation previous to use, than the simple one of turning it once after it is dug from the earth; thus the troublesome and expensive operation of tempering as in ordinary brick making, is avoided. In proceeding to manufacture bricks by this machine, the mould frame before mentioned is suspended by means of its counter weights, at a level with the upper surface of the fixed dies on the moving table, being at the same time partially supported by means of an arrangement of sliding pins attached to the table. The divisions in this frame are now filled with clay by means of a second mould frame of wood, which is placed upon a separate table upon a level with its upper surface.

This wooden frame is provided with a loose bottom, and runs upon a set of small wheels, by means of which it is run in upon the cast-iron mould frame, the loose bottom is then drawn out, and the clay of course fills the divisions in the lower frame. The process of pressing is now commenced by means of the pumps attached to the press, and the moving table caused to approach the fixed top of the press, upon which are fixed a second series of metal stamps of double the depth of those attached to the moving table. Immediately that the mould frame touches these stamps, the sliding pins before mentioned are withdrawn from beneath it, and the upper and lower series of stamps enter the moulds simultaneously and compress the clay to about one-half of its original volume.

The moving table is now allowed to descend, leaving the mould frame attached to the upper dies. To detach the frame and release the bricks requires a considerable amount of pressure, which must be given to the frame alone, in order that the upper dies may push the bricks through their moulds, which they are enabled to do by reason of their great depth. The requisite pressure is given to the frame, by means of two hinged plates of iron attached to the moving table on each side, which are now placed in a vertical position, so that their ends touch the lower surface of the

frame. The pumping is now proceeded with, and the bricks are forced out of their moulds, being received upon a moveable table, which is placed a short distance below the frame for the purpose. The whole process is extremely simple and expeditious, and the bricks made by it, are of such a density, as to resemble ordinary finished bricks even before they are burnt.

By the substitution of cylindrical moulds, in place of the oblong squares used for making bricks, the machine is applicable to the manufacture of earthenware pipes or similar hollow articles.

ON THE FORCE OF THE WAVES IN MOVING MASSES OF ROCK.

By Thomas Stevenson, C. E.

In the Frith of Forth, at the Granton Pier works, on 19th December, 1836, after a gale from the north-east, one stone was moved measuring fifteen cubic feet, or about one ton in weight, and thrown on the beach, after having been built into the wall; and a stone containing 18 cubic feet was moved 30 feet from its place; while the *pierres perdues* mound-stones were washed down to a slope of about 4 to 1.

The following instance, which occurred at the landing slip of the Calf Point, Isle of Man, affords a proof of the great force of the waves even in the Irish Sea. During a gale from the north-west, a block was lifted from its place in the wall and thrown landwards, which measured 123½ cubic feet, equal to about 10 tons weight.

In the German Ocean, we can refer to the Bell Rock Lighthouse,* which, though 112 feet in height, is literally buried in foam and spray to the very top, during ground swells, when there is no wind. It is, therefore, a very important station for making such experiments, because the rise of the spray may be regarded as a scale by which the results of the Marine Dynamometer can be checked or compared.

In the published account of this work there occurs the following statement:—On the 24th October, 1819, the spray rose to the height of about 105 feet above the rock "It may, perhaps, therefore," says the author, "be concluded, that the maximum force of the sea at the Bell Rock is to raise the sprays to the height of about 105 feet above the surface of the rock; and deducting 16 feet, which is the height that the tide rises upon the tower, there is left 89 feet, as the height to which the water is raised. This is equivalent to a hydrostatic pressure of about 2½ tons on the square foot. Since that time, however, there have been still greater proofs of the force of the elevation. On the 20th November, 1827, the spray rose 117 feet above the foundations or low water mark; and the tide on that day rose 11 feet upon the tower, leaving 106 feet as the height of elevation (exclusive of the trough of the sea), being *equivalent to a pressure of very nearly* 3 *tons per square foot.*

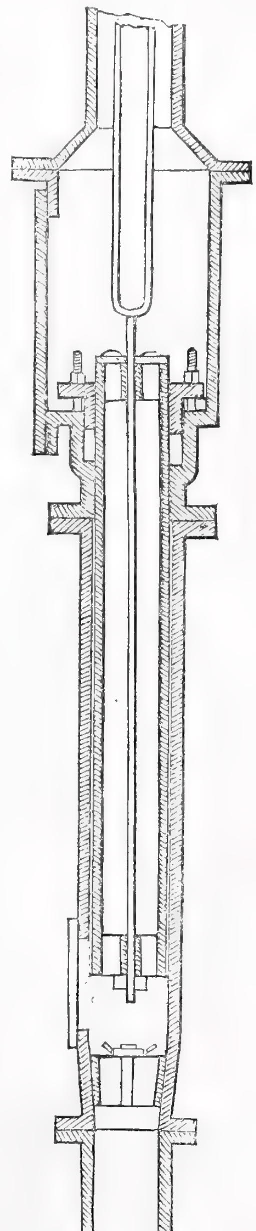
At the island called Barrahead, one of the Hebrides, a remarkable example occurred during a storm in January, 1836, in the movement of a block of stone, which, from measurements taken on the spot, is 9 feet × 8 feet × 7 feet = 504 cubic feet, which, allowing 12 feet of this gneiss rock on the ton, will be about 42 tons weight. This great mass was gradually moved 5 feet from the place where it lay, having been rocked to and fro by the waves till a piece broke off, which rolling down, and jamming itself between the moving mass and the shelving rock on which it rested, immediately stopped the oscillatory motion, and thus prevented the farther advance of the stone.

Mr Reid, the principal keeper of Barrahead Lighthouse, the assistant-keeper, and all the inhabitants of the little island, were *eye-witnesses* of this curious exhibition of the force of the waves; and Mr Reid also gives the following description of the manner in which they acted upon the stone.

"The sea," he says, "when I saw it striking the stone, would wholly immerse or bury it out of sight, and the run extended up to the grass line above it, making a *perpendicular* rise of from 39 to 40 feet above the high water level. On the incoming waves striking the stone, we could see this monstrous mass of upwards of forty tons weight lean landwards, and the back run would uplift it again with a jerk, leaving it with very little water about it, when the next incoming wave made it recline again. We did not credit the former inhabitants of the island, who remarked that the sea would reach the storehouse which we were building; and when these stones were said to have been moved, it was treated with no credit, and was declared by all the workmen at the lighthouse works to be impossible; yet the natives affirmed it to be so, and said if we were long here we might yet see it. They seemed to feel a kind of triumph when they called me to see it on the day of the great storm."

* At such a situation as the Bell Rock, a column of water or of air could be conducted into the interior of the house, and might, in the one case, show the force of each wave as it struck the building by the rise of the water column; or, in the other, by a pressure-guage, show the same result in atmospheres by compression.

IMPROVED PUMP FOR MINES.



Annexed is a sectional drawing of a modified form of a mine pump, which is proposed as an improvement. It requires little description, as its construction is rendered very obvious by the figure. Instead of the ordinary leather-mounted bucket with working barrel, there is a hollow cylindrical plunger which passes through a stuffing-box at the upper end of the pump. The packing is held down by a cover. The plunger has, at each end, a deep bridge, formed to receive the spear of the pump-rod. These bridges allow of the plunger being fixed upon the spear by means of cutters.

Doors are provided to allow of the valves being examined and repaired in case of derangement. By opening that at the upper end of the pump, the cover of the stuffing-box may be removed, and the stuffing renewed. The lids on the top of the plunger can also be changed at the same time if necessary.

The mode of operation is not materially different from that of the pumps in ordinary use. The main advantage which is claimed for it by Mr. Reid, the inventor, consists in this, that, in the common force-pump, the pressure of the superincumbent column of water tends to force up and slacken the stuffing-box, and of course diminish the effective discharge; whereas, in this, as is evident from the drawing, the water pressure is exerted entirely above the cover of the packing, and therefore tends to keep the packing-box tight.

It is therefore not too much to presume that the plan has economy, at least, in the wear and tear of material to recommend it; and, instead of there being any objection offered on the plea of an increase of first cost, the inventor is of opinion that this will rather be diminished than otherwise.

It is hardly necessary to state, that the whole length of the pump, from the surface of the water in the well, to the top of the plunger, must not exceed the height to which water will rise by the pressure of the atmosphere in a vacuum, and ought to be considerably less.

TAPLEY'S BOILER FORCE PUMP.

THE annexed engravings are views of an improvement in force pumps, for which a patent was recently granted to John Tapley, of Frankfort, U.S. The object of the pump is to supply steam boilers with water.

Fig. 1 is a front elevation of it; fig. 2 is a vertical centre section, showing the double plunger at the extreme of its up stroke; and fig. 3 is a horizontal section, taken at line X X, fig. 2. Similar letters refer to like parts.

A and B represent respectively a suction and lifting cylinder, the axis of the one being coincident with that of the other, the two separated a suitable distance, and each made in two parts, at the juncture whereof is confined in the one an induction valve, C, and in the other an eduction valve, D. The outer ends of the smaller of the two parts, A′ and B′,

Fig. 1.

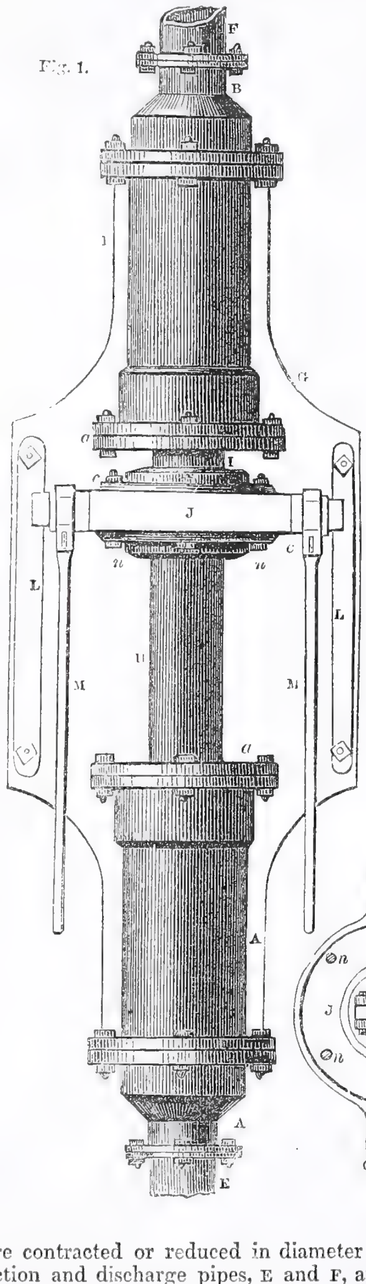


Fig. 2.

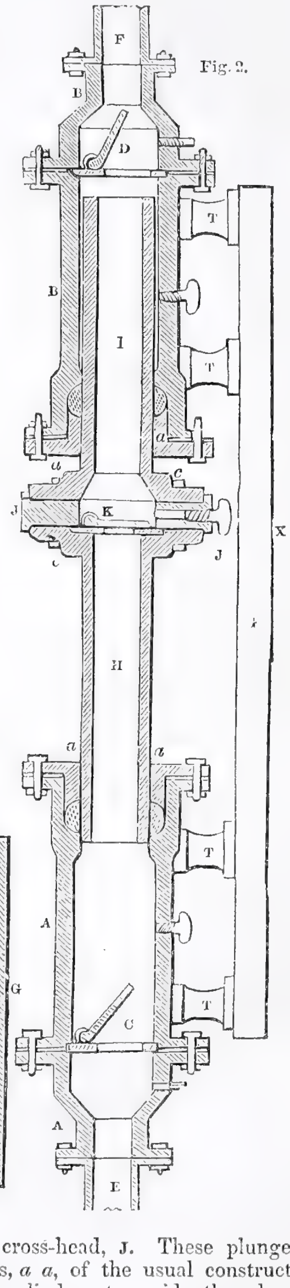
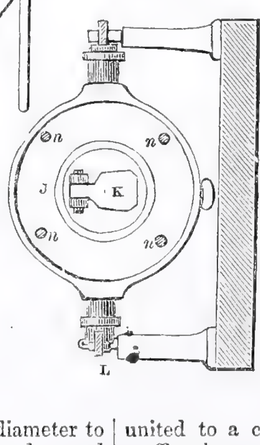


Fig. 3.



of both cylinders are contracted or reduced in diameter to connect with the suction and discharge pipes, E and F, and the two parts of each cylinder are furnished with flanches by which they are bolted together, so as to secure and allow the valves, C and D, to operate freely. The cylinders thus constructed and arranged are mounted on a frame, G, by flanched legs, T, cast with and projecting from the cylinders, or they may be secured by clasp bands, bolted to the frame, and embracing the said cylinders, or in any other convenient manner.

A double plunger is arranged between the cylinders, and working in both. It is composed of two tubes, H and I, united to a cross-head, J. These plungers work through stuffing-boxes, *a a*, of the usual construction, fitted to the ends of the cylinders to guide the plungers and prevent leakage. The diameter of each plunger is a little less than the bore of the cylinders, so that the friction of the plunger is confined to the packing of the stuffing-box, which, when worn out, can be replaced with but little trouble and expense. These plungers are of equal length and diameter, and are secured to the opposite side of an annular cross-head, J, having an opening coincident with the bore of the plungers, but slightly larger, to receive a valve, K, and the bore of the plunger at its end is also slightly enlarged (as seen in fig. 2),

to allow the free action of the valve. The adjacent ends of the plungers are represented as enlarged or furnished with annular flanch-heads, *c c*, and fitted into recesses formed in the adjacent sides of the cross-head, J, and confined by screw bolts, *n n*; but it is very obvious that the three parts may be formed and united together in any convenient manner, provided they are so formed and connected that they will receive a valve between them, and can be easily separated to repair or replace the valve. The length of each plunger is about equal to that of the cylinder within which it works, and the distance of the traverse of each plunger between the cylinders is a little more than one-third of its length, so that it will be seen, when the double plunger is at the extreme of its up stroke, the end of the lower plunger will be near the top of the suction cylinder, and the cross head near the bottom of the lifting cylinder; and in this position of the parts the air floating on the water always passes from the cylinder, A, into the lifting cylinder, B, leaving the water to occupy the entire space of the cylinder, so that, on the descent of the plunger whatever air may be above the water will be expelled in advance of the water. The cross-head of the double plunger is fitted to ways, L L, on which it traverses with the movement of the plungers, and by which the latter are steadied and prevented from turning. The double plunger is operated by attaching connecting rods, M M, to the arms of the cross-head, and uniting said rods to a crank operated by an engine or other prime mover. The action of this pump is very simple, for it will be seen that the double plunger operates in the suction and lifting cylinders at the same time at its up stroke, drawing water into one, A, and expelling it from the other, B; and at its down stroke, displacing the water from the suction cylinder, A, and causing it to ascend into the forcing cylinder, B, the first of these movements of the double plunger acting as a suction and forcing pump, with the induction and eduction valves open, and the latter as a forcing pump with the plunger valve open only. A minute description of the clack-valves is not given, deeming it unnecessary, as they are so well known that any intelligent mechanician will readily understand how to construct and apply them, and to substitute for them valves of other kinds whenever it is expedient to do so. The claim is for the arrangement of two cylinders in a line with each other, connected by a frame, and fitted with valves, stuffing-boxes, and a tubular plunger which works in both, and has a valve arranged in its middle as described, the plunger and each of the cylinders being made in two pieces, at the junction of which a valve is secured, so that, without separating the cylinders and plunger, or dismounting either of them, any one of the valves or the packing of the plungers can with facility be adjusted, removed, or replaced. One of these pumps has been in operation for the past three seasons in the steam saw-mill of T. Cushing, Frankfort, U.S., and has given great satisfaction. It has a tubular plunger of $3\frac{5}{8}$ inches diameter, and supplies seven boilers 40 feet long (each) and $2\frac{1}{2}$ in diameter; and another boiler 36 feet long and $3\frac{1}{2}$ feet diameter. These boilers are in one continuous line, and the pump placed at one extreme end. There are two engines in this mill, and it has been operated by Mr. Cushman for fourteen years. During that period he has tried many feed pumps, but none, he says in a letter now before us, equal to this. Benjamin B. Cushing, engineer, writing from the same place, states that he has witnessed the operation of Mr. Tapley's pump for two years, and that it excels all other pumps within his knowledge for pumping boiling water. He also thinks that it is well adapted for locomotives. For simplicity and durability, this boiler pump appears to have much to recommend it to the attention of engineers.

THE STEAM ENGINE.

CHAPTER II.

THE method by which Savery maintained a supply of water in the large boiler was ingenious, and is worthy of notice here. The small boiler, *d*, fig. 5 (See Chap. I.), was supplied through the pipe, *f*, from the force-pipe, *s*. The pipe, *f*, was furnished with a stop-cock, *e*, by which the water was cut off when required. A pipe, *h*, entered the small boiler, and was continued very nearly to the bottom; the pipe was furnished with a valve opening upwards. The continuation of the pipe enters the large boiler at its upper part, and is cut off close. "When it is thought fit," says Savery, "by the person tending the engine to replenish the great boiler (which requires about an hour and a half or two hours to the sucking of one foot of water), he turns the cock, *e* (fig. 5), so that there can be no communication between the force-pipe, *s*, and the small boiler, *d*; and putting in a little fire under the small boiler, the water will then grow presently hot; and when it boils, its own steam, which hath no vent out, will gain more strength than the steam in the great boiler. The water in the small boiler being depressed by its own steam pressing on its surface, will force the water up the pipe, *n*, into the great boiler; and so long will it run till the surface of the small boiler, *d*, gets to be as low as the bottom of the pipe, and then the steam and water will run together, and by its noise, and the rattling of the clack, will give sufficient assurance to him that works the engine, that the small boiler hath emptied and discharged itself into the greater one, and carried in as much water as is then necessary; after which, by turning the cock, *e*, again, you may let fresh cold water out of the force-pipe, *s* (fig. 5), into the lesser boiler, *d*, as before, and thus there will be a constant motion and continual supply of the engine, without fear or disorder. And inasmuch as from the top of the small boiler, *d*, to the bottom of the pipe, there is contained about as much water as will replenish the great boiler one foot, so you may be certain it is replenished one foot of course."

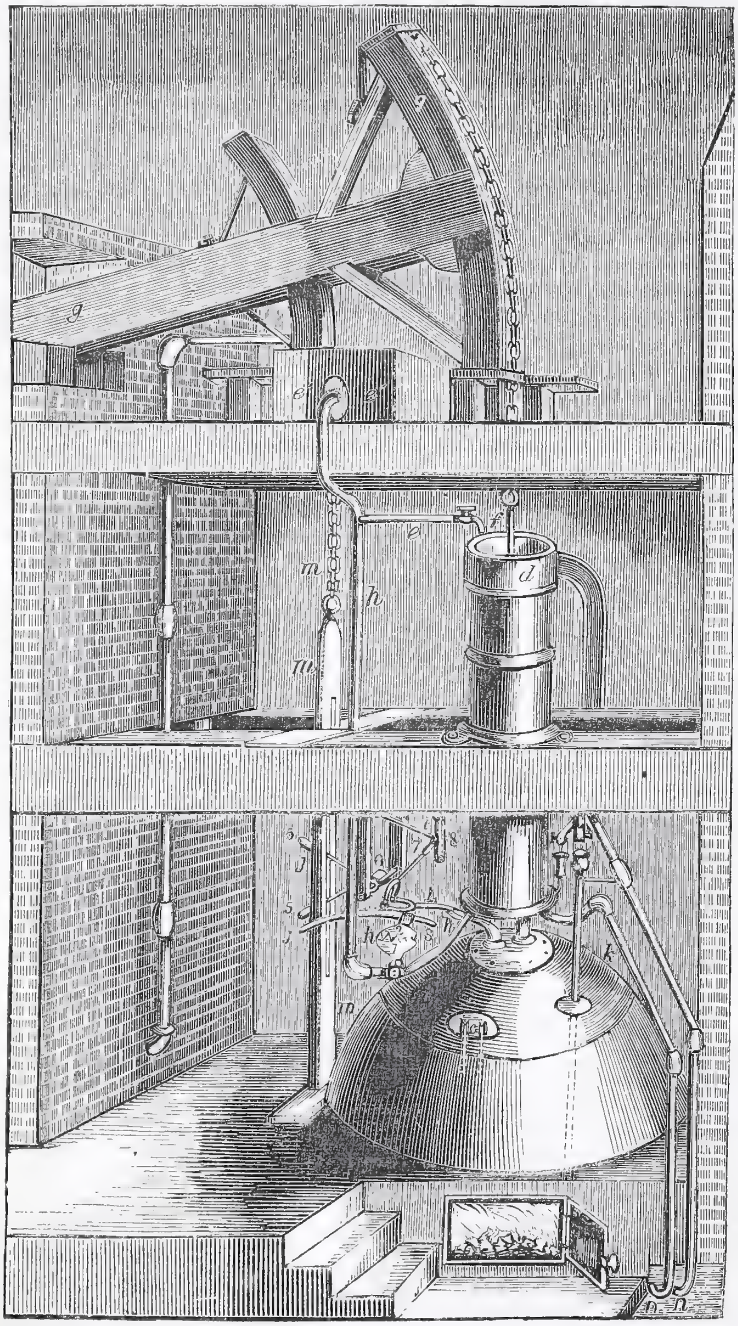
The invention of the apparatus of the "gauge cocks," owes its existence to Savery. We shall illustrate this in a future chapter.

We now come to notice "Newcomen's engine," known as the "atmospheric." Our readers are presumed to be already acquainted with the laws of atmospheric pressure (see chapters on Natural Philosophy), on which depended the operation of the engine; we therefore pass on to the details of its operation. Suppose a cylinder communicating with a steam boiler by a pipe entering at the bottom, to be furnished with a tight-fitting piston, the rod of which is extended upwards, and connected by means of a chain or rope to the end of a sway beam or lever, vibrating on an axis at its centre; at the other end of this beam a weight being hung, which is more than that of the piston. Suppose the piston is at the bottom of the cylinder—when steam from the boiler is admitted to the interior, the piston rises, or rather is pulled up by the weight at the other end of the beam. Suppose, further, that by some application of cold water to the cylinder, the steam in its interior is condensed: the consequence is that a vacuum is formed, and the atmosphere pressing on the upper side of the piston forces it down into the cylinder, bringing with it the end of the beam to which it is attached, and raising the other with its accompanying weight. Suppose the process to be repeated, and, instead of a weight, a pump-rod attached to the opposite end of the beam, and a fair idea of the principle of operation of Newcomen's engine will be attained. The power is obviously equal to the area of the piston multiplied by 15 lbs., the atmospheric pressure per square inch, less the amount absorbed in friction, and the loss sustained through the absence of a perfect vacuum, which is never obtained in practice. In the first engines introduced by Newcomen, the vacuum was produced by throwing cold water over the exterior of the cylinder; this, however, was altered by throwing in the jet of cold water to the interior. This resulted in much accelerating the speed of the engine. This plan, it is said, originated in the following way. To keep the piston tight, a stream of water was allowed to play on its upper surface; on one occasion, the engine was observed to make some strokes in quicker succession than usual; an examination was instituted, when it was found that a hole in the piston admitted the cold water from above it to the interior of the cylinder, thus condensing the steam.

In fig. 6 we give a sketch adapted from one in Stuart's History of the Steam Engine. *a a*, the furnace; *b b*, the boiler; *c*, the

gauge cocks; *d d*, the cylinder; *f*, the piston-rod; *g g*, the main beam; *e*, the pipe to supply the cold water to keep piston tight; *e′ e′*, the cold water cistern, supplied from the pump by the engine; *h h*, the pipe leading the water to the injection pipe; *m m*, the lappet beam for opening and shutting the steam cock

Fig. 6



and injection cock; *k k*, the pipe leading the hot condensing water from the cylinder to the hot water cistern, *n n*. This cistern was placed at a level below that of the cylinder, in order to counteract the atmospheric pressure; had it been level, the water from the cistern would have been forced into the cylinder, in place of the water leaving the cylinder and flowing into the cistern. The air which was taken into the cylinder by the steam or condensing water, was forced out through a "shifting valve" at each descent of the piston. This valve opened upwards, and was kept tight by water.

On its first introduction, the steam and injection cocks were opened by hand; but as this involved much irregularity of operation, and the chances of total cessation through the negligence of the attendant, a plan was ultimately devised by which the engine opened and closed the cocks at the proper intervals.

This plan was first introduced, according to the traditions of the history of the steam engine, by a lad named Humphrey Potter, who, more anxious to play than work, devised an assemblage of strings, &c., by which the cocks were opened and shut. But it was in 1718 that a well-devised arrangement for this purpose was carried into effect by Henry Bighton, a Newcastle engineer. The following will explain the movements of the "hand gear," as the mechanism was termed. A toothed quadrant, 1, fig. 6, was attached to the cock in the injection pipe, *h h*; a second quadrant, 2, geared into this, and was attached to a lever, 3 3, working in a centre; the end of this lever was alternately struck upward and downward by pins projecting from the beam, *m m*, which rise and fall by the movement of the great beam. The steam pipe was closed by a valve inside the boiler; the spindle was continued upwards, and had a bent lever, 4 4, attached to it. To this another lever was attached, and terminating in a fork, 5 5; this vibrates in the centre, 6; to the axis a lever with a weight at its extremities was attached. A pin placed in the beam, *m m*, struck alternately the upper and lower ends of the fork, 5 5, which caused the weighted lever to fall over with some degree of force, and by means of the bent lever attached to the steam cock, 4 4, opened or shut it according to the position of the cam. The following is the operation of the engine.

Suppose the piston to be at the bottom of the cylinder: the steam flowing through the pipe enters the cylinder, and, producing an equilibrium between the upper and under sides of the piston, which rises to the top of the cylinder, the counterpoise at the end of the beam assisting it. When the beam rises, it causes the plug frame to ascend, and one of the tappets thereto attached strikes the end of the lever fixed to the end of the quadrant. This opens the injection cock, which, admitting the water to the interior of the cylinder, condenses the steam therein, and produces a vacuum more or less perfect. Simultaneously with the striking of the quadrant lever, another tappet on the plug frame struck a spanner, which caused the "tumbling bob," or weighted lever, to go over to the opposite side, and, in so doing, actuate the lever attached to the steam valve, and which, being thus closed, prevents the steam from further flowing into the cylinder. The adjustment of the injection and steam valves is such that the latter is quite closed before the former is opened. By the descent of the piston these movements were reversed, the injection cock being shut, and the steam valve opened. By these arrangements, the reciprocating movement of the great beam and pump-rod was kept up. Such was the condition of Newcomen's atmospheric engine before the celebrated Smeaton, the constructor of Eddystone Lighthouse, took it in hand with the view of improving it, and rendering it more efficient and economical in operation. Mr. Smeaton's labours resulted only in improving the details of the workmanship, not in the introduction of any new or striking improvement in principle. We, therefore, do not deem it necessary to go further into their examination, but content

ourselves with referring the reader desirous of knowing the "antiquities" of the steam engine, to the "Artisan Treatise on the Steam Engine," Longmans & Co., London; or to "The Steam Engine: Its History and Mechanism," H. Ingram & Co., London, where a full account will be met with. The following may be taken as a summary of the labours of Smeaton, as given in the first-mentioned of these two works:—"The improvements introduced by Smeaton chiefly resolve themselves into greater care in the construction of the engines, and a better proportion and arrangement of the boiler, and involve neither the application of any new principle, nor any great expenditure of ingenuity. Before Smeaton's time, the manufacture of engines was in the hands of very ignorant mechanics, who did not know the difference between power and force, and their perpetual aspiration was to make the piston exert a great force, without taking into account the velocity of movement necessary to make it operate effectively. It was very rarely the case that the engine was adequately supplied with steam, and when an engine was found incompetent to its work in consequence of this inadequacy, it was generally provided with a larger cylinder, which only aggravated the evil. Then the cylinders were very ill bored, and the condensation from the water lying on the top of the piston, as well as from the water escaping past it, was very considerable, while, at the same time, the piston rarely travelled a sufficient distance in the cylinder, and a great deal of steam was lost every stroke by filling a useless vacuity. The boilers, besides being too small, were generally badly set, the bottom being too far from the fire; and the firing was badly conducted, the coals being filled in a heap in the middle of the grate, instead of being spread evenly over it. The injection cistern was generally set too low, by which means the water was not adequately dispersed within the cylinder, and the valve gearing was for the most part so constructed that the regulator did not open fully, by which means the steam was throttled, and a heavy counterweight was necessary to suck the steam into the cylinder, which, of course, had afterwards to be raised at an expenditure of power. These faults Smeaton corrected; his plan of sheathing the under side of the piston with wood, prevented much of the condensation by the water lying on the top of it, and the use of more perfectly bored cylinders, which the establishment of the Carron Iron Works, about this time, enabled him to obtain, obviated the condensation from water trickling down the cylinder sides. The boilers he introduced were very effectual and satisfactory."—*Artisan Treatise, p.* 9.

We have now reached the great era in the history of the steam engine—the period of the labours and discoveries of the celebrated James Watt. Before describing the mechanical arrangements of the steam engines which owed their existence to his genius, we shall present our readers with a few notes, historical and introductory, in connection with this great man.

James Watt was born in the town of Greenock, on the banks of the Clyde, in the year 1736. When in his sixteenth year, he was apprenticed to a "mathematical instrument maker or optician," as he was designated, but who, to those occupations, added others of a very heterogeneous character, as maker and "repairer of fiddles," "tuner of spinnets," "whitesmith," &c., &c. Remaining only two years with this "useful man, at almost everything," Watt repaired to London, where he succeeded in obtaining employment with a regular mathematical instrument maker. Compelled to return to Glasgow through ill health, he, after many difficulties from obstacles thrown in his way in consequence of his not being a "freeman" or "burgess" of the town, obtained the situation of mathematical instrument maker to the University, with apartments in the College, so that he could carry on his business free from all interference.

Although Watt's attention was directed to the improvement of the steam engine by Professor Black so early as 1759, nothing, save an experiment or two, was effected by him till two years afterwards, when a model of Newcomen's engine was sent him from the College to repair. During his labour in this way, he was struck with the defects of the engine, and at last determined to master the principle of the machine, and to ascertain the cause of its defects as an economical prime mover. A series of experiments led him to the conclusion, that the great waste of steam was mainly attributable to two causes—the loss by radiation of heat from the cylinder, and that sustained by cooling down of the cylinder at every stroke, by the admission of the cold injection water. That the latter was the principal cause of loss, was proved by the use of means—a cylinder of wood—to prevent the radiation of heat from the cylinder, which resulted in no great saving, and was obviously unsuited in other respects for practice. Two other points also attracted Watt's attention—the great quantity of injection water required, and the great heat which the water acquired by condensation. By allowing steam from a tin kettle, to flow into a vessel of cold water, until it was boiling hot, he found that the water had gained nearly a sixth part of the steam used in heating it. From this he drew the conclusion, that a "measure of water converted into steam, can raise about six measures of water to its own heat; or eighteen hundred measures of steam can heat six measures of water." "Being struck," says Mr. Watt, "with this remarkable fact, and not understanding the reason of it, I mentioned it to my friend, Dr. Black, who then explained to me his doctrine of 'latent heat,' which he had taught some time before this period (summer of 1764); but having been occupied with the pursuits of business, if I had heard of it, I had not attended to it, when I thus stumbled upon one of the material facts by which that beautiful theory is supported."

From his experiments, it was quite clear that the great desideratum to be effected was the *keeping of the cylinder as hot as the steam which entered it.* How to do this was the problem to be solved, and to effect it he set all his energies to work. For some time he was baffled by the difficulties of the task, but at last the grand idea developed itself, "that if a communication were opened between a cylinder containing steam and another vessel which was exhausted of air, the steam would immediately rush into the empty vessel, and if that were kept very cool by an injection or otherwise, the steam would continue to enter until the whole was condensed. And if an air-tight cover were placed on the cylinder, steam might be admitted to depress the piston into a vacuum instead of the atmosphere."—*Stuart's History.*

Having thus discovered the grand principle, Watt found all the details of operation a comparatively easy task. Watt now gave up his occupation of mathematical instrument maker, and devoted his attention to land surveying, and, ultimately, to civil engineering. To work out his invention into practice, took a considerable portion of his time during three years. At last, having become thoroughly convinced of its importance, and being fortunate enough to fall in with the celebrated Dr. Roebuck, a man of high attainments and of a speculative mind, and who was, moreover, possessed of the grand necessary—money—an arrangement was entered into between them, by which Roebuck was to find the necessary capital for patenting the invention and for manufacturing the engines, on condition of obtaining two-thirds of the profits. In 1769, accordingly, Watt took out his patent, of which the following is the specification:—

"My method of lessening the consumption of steam, and consequently fuel, in fire-engines, consists of the following principles:—

"First, That vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire-engines, and which I call the steam vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it; first, by enclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and thirdly, by suffering neither water nor any other substance colder than the steam, to enter or touch it during that time.

"Secondly, In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam vessels or cylinders, although occasionally communicating with them; these vessels I call condensers; and, whilst the engines are working, these

condensers ought at least to be kept as cold as the air in the neighbourhood of the engines, by application of water, or other cold bodies.

"Thirdly, Whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

"Fourthly, I intend, in many cases, to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office.

"Lastly, Instead of using water to render the piston or other parts of the engines air and steam tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver, and other metals, in their fluid state.

"And the said James Watt, by a memorandum added to the said specification, declared, that he did not intend that anything in the fourth article should be understood to extend to any engine where the water to be raised enters the steam vessel itself, or any vessel having an open communication with it."

Proceeding to work under the agreement with Dr. Roebuck, Watt encountered many difficulties, chiefly arising from defective workmanship, which retarded amazingly the progress of the invention. An apparently insuperable difficulty also presented itself in the failure of Dr. Roebuck, which threatened to blight Watt's prospects of ever reaping any pecuniary benefits from his invention. But this untoward circumstance only offered a proof that all things are ordered for the best, as it was the means of introducing to Watt the celebrated Matthew Bolton of Soho, as a partner in the manufacture of the engines —Roebuck having transferred his interest in the patent to this gentleman. No circumstance could be more fortuitous than this, for it introduced Watt to a man who possessed not only a large capital, a fine factory calculated to produce the finest workmanship, but a business energy and commercial talents of a high order. Henceforth, Watt's life was but a record of success—one which brought him in fame, and the more solid advantages of wealth. "To a man like Watt," says Stuart, "so unfitted from feeling and habit to stand alone, nothing could have been more auspicious than his gaining the protection of two such men in succession. Obstacles were seen by either only to be surmounted, and they both possessed, in an eminent degree, the master-art of infusing into all around them a portion of their own matchless energy. Projectors themselves, they were considerate of his feelings, and knew how much the flow of thought in irresolute or hesitating geniuses is quickened by the kindness and condescension of a patron. Assisted by their experience, and animated by their generous approbation of what he had already achieved, he was roused and carried onward to impart greater perfection to his mechanism."

On considering these circumstances attendant upon Watt's experience, some have been inclined to urge a "poverty of mind," and an inability to design and arrange his details. But it should never be forgotten that the circumstances under which Watt was placed as regards mechanical facilities, were vastly different from those which now exist. In his time, the tools to aid in construction of machinery were as few in number as imperfect in principle. The very parts required to perfect the operation of the engine, as the cylinder, piston-rod, &c., necessitated other inventions by which they themselves could be constructed. In fact, the chief difficulties he had to contend with were those of construction; and hence arose the great and immediate advantages attendant upon his connection with Bolton: this gentleman had every facility in the department of tool mechanism, and spared no labour or money to perfect what he had, as well as to bring out others which the exigencies of the manufacture rendered necessary. Bolton attended to the construction of the mechanical details and the commercial features of the undertaking; Watt devoted his attention to principles and improvements in the mechanism; hence the success which waited upon this felicitous union of the physical energies, and business capabilities, and mental powers.

In 1800, the period of monopoly granted to Bolton and Watt expired, and the great inventor retired from that public position which had given a world-wide celebrity to his name, to the enjoyment of the wealth which followed in its train. After a life "full of years and honour," Watt died in 1819, on the 23d of August.

Before proceeding to describe the details of Watt's invention, we must devote a few sentences to the consideration of the genius and the character of this great man. As to the first, we do the reader a service by presenting the celebrated *éloge* on Watt by M. Arago, and as to the second, the no less celebrated characterization of Jeffrey:—

"Gentlemen This creator of six or eight millions of workmen—of workmen indefatigable and industrious, among whom the arm of authority is never called upon to interpose for the suppression of revolt,—this man, who, by his brilliant inventions, conferred upon England the means of sustaining itself during a political convulsion, where its very existence as a nation was endangered,—this modern Archimedes, this benefactor of the whole human race, whose memory future generations will eternally bless—what was done to heap honour upon this man? The peerage is in England the first of dignities, the highest of national rewards. You will naturally suppose that Mr. Watt was at least elevated to the highest rank in the peerage! Such a thing was never even thought of.

"Futurity will behold Watt appear before the grand jury of the inhabitants of the two hemispheres—they will see him penetrating with the aid of his mighty machine into the bowels of the earth in the short period of a few weeks, to the depths where, before his time, it would have required a century of painful labour to arrive, and there opening up spacious galleries and mines, clearing them in a few minutes of the immense volumes of water that encumber them, and snatching from virgin earth the boundless mineral wealth deposited there by bountiful nature. Uniting delicacy with power, he will be seen twisting with equal success the immense folds of the gigantic cable, by which the ship of the line embraces in safety her anchor in the midst of the tumultuous tossing waves; and the microscopic filaments of the delicate muslins and the aerial lace, which float on the zephyrs of fashion. A few oscillations of the same machine will bring into culture extensive swamps; and fertile countries will be rescued from the periodic and deadly miasmata raised up by the burning heats of a summer sun.

"Population, well-fed, well-clothed, well-warmed, increasing with rapidity, is fast covering with elegant mansions the surface of countries, formerly the deserts of the world, and which eternal barrenness appeared to condemn to the beasts of prey. In a few years, what are now but hamlets, will become important cities: in a few years, towns such as Birmingham—where already one reckons three hundred streets—will take rank as the largest, most beautiful, and wealthiest cities of a powerful kingdom. Transferred to our ships, the steam engine will replace an hundredfold the power of triple and quadruple ranks of rowers, from whom our forefathers exacted a labour reckoned among the severest punishments of the most atrocious criminals. The steam engine, in conclusion, drawing in its train thousands of travellers, will traverse the railway with far greater velocity than the best race-horse loaded only with his pigmy jockey!

"There, gentlemen, is a rapid sketch of the legacy conferred on the world by that machine which the ingenuity of Watt carried to such admirable perfection. We are accustomed to quote the 'Augustan age'—the time of Louis the Fourteenth. Noble spirits have already arisen, who have thought it just to speak of the age of Voltaire, of Rousseau, of Montesquieu; for my part, I pronounce, without hesitation, that when to the immense services which the steam engine has already achieved, there shall be added all the marvels it promises for the future, a grateful world will also cite the ages of Papin and of Watt."

Modes of Flowering continued.

Parts of Fructification resumed.

BOTANY.

CHAPTER XIV.

PHENOMENA OF DESCENDING SAP CONTINUED—SECRETIONS.

We now proceed to a consideration of the various vegetable secretions which go far to make up the solid parts of plants.

1. Protein Compounds.—Protein is a greyish-white flocculent precipitate, first obtained by Mülder from treating albumen, casein, horn, and fibrin, with a solution of potash, and afterwards mixing with a slight excess of acid; and it is so called (πρωτεύω, to hold the first place), on account of its being the most important among the albuminous principles. It is without smell or taste, and is insoluble in water, alcohol, ether, and essential oils. It attracts moisture rapidly from the air, and loses water at 212°, but, by long-continued boiling, acquires the property of solubility. By the application of strong heat, it is decomposed with the production of ammonia and pure charcoal. It is characterised by the presence of nitrogen, and analysis shows its composition to be the same from whatever source it is procured:—

Carbon,	55·30	Nitrogen,	16·02
Oxygen,	21·34	Hydrogen,	6·94

The modifications of which protein is the basis are albumen, fibrin, casein, and emulsin.

The colourless fluid in an unboiled egg is an example of animal *albumen.* Vegetable albumen is found in the green substance of plants in general, in the fresh shoots of trees, in the sap of cauliflower, turnips, mangel-wurzel, &c., and in the almond and other emulsive seeds; but it is collected most abundantly in those vegetables which ferment without yeast, and afford a vinous liquor. Wheat is said to contain $\frac{3}{4}$ to $1\frac{1}{2}$ per cent.; rye, 2 to $3\frac{3}{4}$; barley, $\frac{1}{10}$ to $\frac{1}{2}$; and oats, $\frac{1}{8}$ to $\frac{1}{2}$ per cent. At first it is soluble in cold water; but, after being coagulated by heat, which requires a temperature of 140° to 160°, it ceases to be again soluble. It is insoluble in alcohol, sparingly soluble in acids, and readily soluble in alkalies, from the latter of which it is precipitated by acids. In 100 parts, it consists nearly of—carbon, 54·84; hydrogen, 7·09; oxygen, 21·23; nitrogen, 15·83; phosphorus, 0·33; and sulphur, 0·68.

Fibrin, called also gluten, is combined somewhat largely in the juices of plants in a dissolved form, and though partly soluble in water and insoluble in alcohol, coagulates spontaneously in fruits and seeds. It abounds in wheat, barley, and oats, and is represented by the ductile elastic matter obtained by kneading any of these cereal grains in a fine sieve, and washing the mass with cold water. The milky liquid passing through, contains starch which subsides, also albumen and mucilage which are suspended. The substance which sticks to the sieve, and forms an adhesive paste resembling glue, is gluten, with the addition, in a detached state, of a little woody fibre. The albumen in this composition may be afterwards entirely separated by being made to coagulate in flaky particles, when the solution is concentrated over a vapour bath. In its moist state, it is of a dirty grey colour, possessed of considerable tenacity, fibrous, ductile, and elastic; and in this state has a tendency to putrefy and to exhale an animal odour. About half its weight is lost in drying, which any subsequent immersion fails to change or recover; and thus hardened, it is of a glistening greyish-green colour, brittle, and resinous in the fracture. Wheat is usually regarded as supplying gluten in its most perfect state. According to analyses of several samples of French and Odessa wheat, Vauquelin found between 56·5 and 73 per cent. of starch, 7·3 to 14·5 of gluten and albumen (though other experimentalists have extended the average of these principles when united to 16 or 17 per cent.), 4·2 to 8·5 of sugar, 2·8 to 5·8 of gum, 1·2 to 2·3 of woody fibre, and 8 to 12 of water. Hermbstädt ascertained the proportions of starch and gluten in 100 lbs. of the same crop of wheat, differently manured, to be as follows:—

Manure.	Starch.	Gluten.
Blood,	41 lbs.	34 lbs.
Sheep dung,	42 "	33 "
Horse dung,	62 "	14 "
Cow dung,	62 "	12 "
Vegetable manure,	66 "	10 "

The relative proportions have been subsequently extended to other kinds of grain, in which a difference is observable, both in the average quantity of gluten present, and in the variation to which the quantity is liable.

	Barley.		Oats.	
Manure.	Starch.	Gluten.	Starch.	Gluten.
Blood,	$66\frac{1}{2}$	$6\frac{1}{2}$	60	$5\frac{1}{2}$
Night soil,	66	$6\frac{1}{2}$	60	5
Sheep dung,	$66\frac{1}{2}$	$6\frac{1}{2}$	61	$4\frac{1}{2}$
Horse dung,	66	$6\frac{1}{2}$	$61\frac{1}{2}$	$4\frac{1}{2}$
Cow dung,	69	$3\frac{1}{2}$	62	$3\frac{1}{2}$
Vegetable manure,	69	3	$66\frac{1}{2}$	$2\frac{1}{4}$
Unmanured,	$69\frac{1}{2}$	3	$66\frac{1}{2}$	$2\frac{1}{4}$

The proportions of starch and gluten, indeed, have been found to differ, not only in different grains, but in the same species or variety, as well according to the season when sowing, as the manure applied to the land. Any fixed amount of the elements which produce gluten does not appear essential to the growth of plants; but the hard and soft properties of boiled grains, and the feeding, malting, and distilling qualities of stems, seeds, or roots, depend on the actual quantity of gluten entering into their composition. Gluten is the most nutritive part of flour, and, in southern Italy, enters extensively into the manufacture of macaroni and vermicelli. According to Mülder, dried gluten consists of—

Carbon,	54·56	Oxygen,	22·13
Hydrogen,	6 90	Phosphorus,	·33
Azote,	15·72	Sulphur,	·36

Legumen is the vegetable analogue of the animal product termed casein—a component of milk, and separable from it as the basis of cheese. It was first obtained by Braconnet from peas; but it may be also easily procured, to the amount of about 18 per cent., by straining in cold water kidney beans and lentils which have been previously bruised in a mortar. It forms an essential part of leguminous and oily seeds. It is insoluble in alcohol, but dissolves in the alkaline carbonates. It contains, like its kindred principles, some sulphur and azote.

Emulsin or *Synaptase* has been investigated by Boullay, Vogel, Robiquet, and Boutron, Liebig, and Wöhler. It occurs in the form of emulsion—a term applied to mixtures having a milky appearance, and which are either partial solutions or merely mechanical suspensions of oily or resinous substances. It is supplied by both the sweet and bitter almond, and synaptase is the principle by which the oil is suspended in their emulsion. Sweet almond consists of about 54 per cent. of a bland fixed oil, and 24 per cent. of the present variety of soluble albumen, together with 22 per cent. of sugar, gum, and water. The measure of fixed oil in the bitter almond is somewhat less, and the synaptase somewhat more, than in the sweet variety; and Robiquet ascertained that it held from 1·0 to 2·5 per cent. of another principle peculiar to itself, termed Amygdalin, which is an azotised body, crystalline, bitter, colourless, and free of odour. A singular property of this substance merits mention, that when water comes in contact with the pulp of bitter almond, a volatile oil is produced, composed of hydrocyanic acid, under the mutual action of amygdalin and synaptase with the water.

2. Neutrals are vegetable substances, in which oxygen and hydrogen exist in the same ratio as in water, and are characterised as carbonaceous compounds, from the union of the elements of water with the carbon of carbonic acid. The products which belong to this class are nearly similar in their essential composition. They are consequently found to be intermediate, and calculated, from their power of solubility, to pass onwards from one form to another. Gum becomes convertible into starch, starch into sugar, and sugar into woody

fibre. The same elements are applied to varied purposes, with a unity of design no less evident than impressive.

Gum.—A colourless, tasteless, and inodorous body, uncrystalline, and insoluble in alcohol, is the immediate result of a chemical change of the sap in the leaf, and is the simplest of the organic forms which that matter assumes. Its presence is of universal occurrence among the vegetable juices; and, from its bland qualities and easy capability of transmisson, it undergoes in its progress those elaborations which give rise to other products. It is prepared by the plant for its own nourishment, to which it is highly conducive, and is indeed the basis of vegetable nutriment, affording even a support to the natives who collect it, and to monkeys and other inferior animals. It exudes either spontaneously or incised, and, when escaping to the exterior of the bark, becomes concrete or even pulverizable from masses called *tears*. Gum is of several kinds, some being entirely soluble in cold water, as mucilage and arabin; while others merely swell up under it into a gelatinous paste, as bassorin, cerasin, and pectin. Mucilage is gum in a dissolved state, and exists generally in the juices not exuded. It may be seen in many of the Cryptogamia; also, in Malvaceæ, Liliaceæ, Linaceæ, Orchidaceæ, and most of the Boraginaceæ. Arabin is the principle of the purest gum—gum-acacia, commonly called gum-arabic, which, according to Gay-Lussac and Thenard consists of 100 parts—carb. 42·23, hyd. 6·93, ox. 50·84. It is yielded in greatest abundance by old trees that have suffered impediment or stunting, and is collected in hot and dry weather after the rainy season has softened their bark, and then made it liable to split. A variety of gums, closely approaching in nature to gum-arabic, is to be met with in the drug markets. These are Gum-Senegal, Barbary gum, and East India gum, all obtained of different species of Mimosa or Acacia, growing in Arabia, India, Nubia, Senegal, &c. The specimens vary from the size of a pea to that of a walnut, or larger; are irregular in shape, tinted from white and yellow to a dark wine colour, with taste mawkish and glutinous. Bassorin forms the chief ingredient in gum-bassora and gum-tragacanth—the produce of several species of Astragalus. It is conjoined also in the nutritious substance called Salep, obtained from the tuberous roots of one of the Orchis tribe. Cerasin was found by Guerin in the gum of the Cherry (*Cerasus*). It also occurs in Plum and Almond trees. Pectin is the gelatinous principle of pulpy fruits—as Apple and Pear—from which it is obtained by pressure and evaporation. When dry it resembles isinglass, but is scarcely soluble in water, and has no acid properties. It is found in many fruits and esculent roots in the form of pectic acid, which is effected by the action of alkalies, as carbonate of potash, on the pectin.

Starch may be considered a peculiar product of vegetables, and is either not found at all or merely to be traced in animal cells. It is called by botanists farina, and by chemists, fecula. It is the most abundant of all the nutrient secretions, and is a more permanent compound than the last, adapted for retention in the organs of plants. Payen and Prout's analyses give a composition of 44 parts by weight of carbon, 6·22 hydrogen, and 49·78 oxygen; and consequently, $C^{12} H^{10} O^{10}$. In point of general appearance, it is a white insipid powder; when pure, nearly devoid of odour and taste, and of density 1·53. It occurs enclosed in cases in the form of microscopic granules, irregularly shaped, generally globular or oval, and seldom angular; and the same case contains several of these masses differing in size often in the same case, the smallest occupying the circumference. The manner of their disposition varies in different plants. In the potato, for instance, the grains are striated transversely; in wheat, they are interposed betwixt successive layers of vascular deposit, and in the maize, again, the arrangement is quite different. A knowledge of these appearances by the microscope is highly useful in detecting the frequent frauds which are practised on the public, from palming less nutritious granules of common plants. They are, besides, highly interesting from the views which they disclose under polarized light. A gentle heat expels moisture out of starch; but in its ordinary condition, it contains about 12 per cent. of water; and if exposed to an atmosphere charged with it, it will absorb double that quantity without losing its dry appearance. In the proportion of from $\frac{1}{21}$ to $\frac{1}{40}$, it suspends drugs in the state of powder. Strong heat reduces it to an earthy and saline residuum that is scarcely perceptible; while frost is commonly seen in potato, apple, and parsnip to have the effect of fermenting it into sugar. It is insoluble in concentrated sulphuric ether; but diluted sulphuric acid has long been known to resolve it into sugar; and when compounded with nitric acid, malic and oxalic acids are formed. A treatment with alcohol removes from it a little essential oil, but leaves it still undissolved. It is scarcely acted on by iodine in a state of simple mixture with cold water; but when solution takes place by triturating the water, a dark purple colour is struck; and if hot water has been employed and allowed to cool, a deep blue iodine is precipitated. It is insoluble in simple cold water when gently mixed in it; but a brisk agitation either dissolves or so intimately suspends it as to resist filtration. After, however, being raised to a temperature above 212°, it acquires an easy solubility in water, resembling, on cooling, an opaque loose jelly.

The granules of starch are obtained from a great variety of plants. They exist largely in many fleshy roots and rhizomes. Arrow-root is a familiar example, the produce of Maranta arundinacea and M. indica. A glistening variety, called Tous-les-mois, is extracted in the West Indies from two or three species of Canna. "It is not a little remarkable," says Dr. Lindley, writing on Spurgeworts (Vegetable Kingdom, 280, 281), "that here, as in so many other cases, we should find, in a very dangerous natural order, such an abundant secretion of starch as renders certain species useful for food when the acrid matter is removed. This is most especially the case with the Mandioc plant—a shrub about eight feet high, extensively cultivated for food all over the tropical parts of the world. Of this plant, the large root, weighing as much as thirty pounds, is full of venomous juice, which, if taken internally, produces death. The roots are rasped, the pulp well bruised and thoroughly washed, after which it is placed on iron plates to be heated. In this way the venom is washed out or driven off, and the residue becomes cassava. The powder which floats off in the water is a very pure starch, which, when it settles down, becomes tapioca." The potato furnishes a magazine of pearly and sparkling grains, each with a hilum or point, supposed to be an opening into the cell. The influence of soil, the variety of seed and manure employed, the mode of cultivation, and the times of planting and digging, affect very sensibly the quality of starch obtained from this tuber. Yams are the large fleshy farinaceous tubers of the principal part of the species belonging to the genus Dioscorea. The corms of certain Arads are roasted or boiled for use under the name of eddoes, and the powder of Arum maculatum is exported from the isle of Portland, as sago. Inuline is a starch spontaneously deposited from a decoction of the roots of Elecampane (*Inula helenium*); but the same principle may be obtained from Dahlia variabilis and Helianthus tuberosus. It is a white powder, insoluble in cold water, but soluble in hot, from which it is deposited on cooling. Starch is abundant in the pith and trunk of most of the Palm tribe. The immense forests of Sagus lævis and S. genuina, which clothe the Molucca ranges, furnish the finest sago, and each individual tree has been computed (Rumphius, ii. 148) to supply from 600 to 800 lbs. of pure starch. In Ceylon and other hot countries, where Caryota ureus grows, the natives make the pith into bread; and Small Date palm forms a common article of diet to the people of Coromandel. Gingerbread tree and Zalacca edulis are well known among palms to the inhabitants of Polynesia, Egypt, and India, for the farinaceous food they provide. A similar material is extracted from the race of Cycads, holding an important place in the sustenance of the Caffres, Japanese, Mexicans, and West Indians. Not only the rhizomes and seeds, but the stems of water-lilies contain a considerable quantity of starch. The larger species called Victoria, for that reason passes by the name of Water Maize in South America; and other species, distributed in Turkey, Senegal, India, and China, are eagerly sought after for their nutritive qualities. It is to an amylaceous substance present

in lichens, hence called lichenin, consisting of $C^{12} H^{10} O^{10}$, that edible species are found in Lapland, and others, on which the hunters of Canada and the nomade tribes of Asia are often forced to subsist. Starch is occasionally found in the receptacles of flowers, as artichoke; in pulpy fruits, as apple and pear, and sometimes even leaves are replete with it, as in Bread-nut. But it nowhere prevails so much as in different kinds of grains or seeds, forming in the Cerealia alone between 60 and 75 per cent., with gluten, sugar, and gum. The best starch prepared in this country is procured from wheat. Oats, barley, rye, rice, maize, and millet, are amongst the commoner forms from which it is exhibited. Indian bean, indian corn, common bean and pea, and the other leguminous species are well known. The succulent heads of Bread-fruit and Jacca-tree owe their edible qualities to the large quantities of starch they secrete. The value of cocoa-nut is widely appreciated, and different species of Musa produce the banana and plantain, of the former of which it has been said—"the same extent of ground which in wheat would only maintain two persons, will yield sustenance to fifty." The Mastworts, comprising oak, hazel, beech, and chestnut, require merely to be referred to for the starch they contain, combined, as it is, with other principles of an astringent and oily nature.

A secretion so generally and plentifully diffused is reserved for the purposes of development, and serves to vegetables the use of fat in the animal kingdom. Accordingly, it is deposited in all the parts of plants which afford nutriment to the growing organs. During full vegetation, minute granules of starch are seen enclosed in the globules of chlorophyle which occupy the interior of individual cells; but they are deposited at large within the compartments of the cellular tissue. Mohl states (Ann. des Scien. Nat. Bot., Ser. 2, ix. 166), that in deciduous trees the fecula prepared in the leaves descends into the stem during autumn, and furnishes thence, in spring, materials for evolution of the buds. Carrots and turnips, by exhausting their supply when run to seed, become unfit for use. From experiments made with 240 lbs. of potatoes left in the ground, it appears that the stock of starch gradually increased to a specific measure during autumn, but began to decrease as the requirements of germination drew upon it in spring. The rising and falling of the material in pounds, may be observed to vary with the months after the mode of a thermometer:—

In August the starch rose from			23 to 25 lb.		
" September,	"	"	32	" 38	"
" October,	"	"	32	" 40	"
" November,	"	"	38	" 45	"
" Winter,	" was stationary.				
" April,	"	fell from	38	" 28	"
" May,	"	"	28	" 20	"

The manner of liberating the starch granules from the woody tissue of plants, is simply by tearing the tissue in cold water, and cleansing the granules which have escaped. To obtain it tolerably free, the pulp ought to be bruised, rasped, or kneaded in a cloth with successive washings, to exclude the mucilage, gluten, phosphatic salts, and other residuary matters which may be present. These, for the most part, remain enclosed in the cloth, while the starch suspended in the water passes to the bottom of the vessel which receives it, and is afterwards dried. In this way, diseased potatoes, otherwise worthless, may be rendered profitable to the frugal housewife, while the cleaned pulp, thoroughly dried and ground, will form a brown meal for the tenant of the sty. If manufactured on a large scale, the process of kneading is superseded by a stream of water, which is allowed to stand for a few days in summer, and for a week or two in winter, when fermentation takes place, which dissolves or suspends the associated principles. The acetic acid, technically termed *sours*, is then drawn off, and, being cast upon sieves and washed, the impurities are retained; but the starch is carried into large vessels called *frames*, where it is allowed to subside, and the sour water or *slimes* drawn from it is removed. The starch, after another washing and sifting, subsides, and, being placed in boxes perforated with holes and lined with canvas for drying, is cut and exposed on bricks to the heat of an oven, where it is completed as white or French starch. In this form, its dietetic uses are very extensive, from its capacity of easy digestion, and its nutrient and demulcent properties. When prepared with one-fifth to one-twentieth of water, it forms a culinary mucilage for stiffening linen; in which case a little smalt or indigo is usually added, for the purpose of imparting a more agreeable hue to the dull white of linen. When a sufficient temperature is adopted to acquire for it a reddish-brown tint and gummy consistence, it is used under the name of British gum for the thickening of mordants in calico printing.

A key to the most interesting of these facts may be obtained by inquiry into the structure of the starch granule, and some special relations of a chemical nature attach to its component parts. We will now, therefore, pursue this inquiry in its particular bearings.

Raspail had observed that each granule was surrounded with a delicate pellicle of its own; but the subsequent experiments of Payen and Persoz demonstrated that the granule consists of two proximate principles—an external envelope, which has been named amylin, and a mucilage enclosed in it, termed amidin or amidone. These constituents may be exposed, either by the action of hot water, or by the principle called diastase, immediately to be explained; both agents turn what is insoluble into soluble. It is owing to the insolubility of the outer membrane in cold water, that the inner starch is inseparable in raw wheat, flour, &c., from its associated gluten and other matters; but while the coats of the cell in which it is hoarded protect them from the immediate action of surrounding water, yet boiling water has the effect of bursting the tegument and causing the mucilage to escape. Diastase, in the natural course of germination, accomplishes a rupture of the same nature, and renders the contents available for dispersion. The method prescribed by the Edinburgh College for obtaining both parts is as follows:—"If starch be mixed with four parts of water and a thousand of its weight of diastase, and the mixture be maintained steadily at a temperature between 150° and 175° F., the globules in a few minutes burst, a solution is obtained nearly as fluid as water, and the tegumentary membranes of the globules gradually subside. Amylin is easily procured by allowing the mixture to remain for a few hours at the temperature specified, till the liquor no longer becomes blue with iodine when cooled. The saccharo-mucilaginous solution, into which the amidin is thus entirely converted, is then removed after rest and subsidence. The precipitated teguments are next to be thrown on a filter, washed thoroughly with water to remove any adhering gum and sugar; and, finally, the spongy mass which remains is dried over the vapour-bath. This is amylin. In order to obtain pure amidin, the liquid mixture produced by the action of diastase, as soon as complete liquidity is accomplished, must be suddenly raised to the temperature of 200° or 212°, in order to prevent the further changes which the presence of diastase would otherwise effect. The liquor must then be cooled and left at rest till the teguments subside. The clear supernatant fluid is next to be concentrated by means of a heat between 212° and 230° to the consistence of sirup, and skimmed from time to time, as the teguments which had not subsided rise to the surface. From this sirupy fluid, dry amidin may be obtained, pure enough for economical purposes, by simple evaporation in thin layers. But for attaining chemical purity, it is advisable to throw down the amidin by means of rectified spirit, and to wash it on a filter with that liquid, after which it is to be redissolved in boiling water, and evaporated to dryness over the vapour-bath."—*Christison's Dispensatory*, Pp. 125-6.

Amylin forms four or five parts in a thousand of starch. A trace of volatile oil is usually present in any quantity of its detached molecules; but when pure, amylin is white, translucent, and tasteless. It appears to be of a woody nature, and probably proceeds from fibrin in a decomposed or fermenting state. A prolonged ebullition swells it up, but leaves it undissolved. Alchohol, iodine, and diastase have no action on it. A diluted sulphuric acid forms with it sugar, and when digested with nitric acid, it yields malic and oxalic acids.

Amidin, on the other hand, when dry, is elastic and brittle. By trituration it mixes with water, and, at 150°, dissolves in

that element, forming a jelly on cooling, from which it returns to its former state and properties, if dried. Iodine renders blue both the cold emulsion and the hot solution, and both are precipitated by an infusion of galls, lime, baryta, and diacetate of lead. One hundred parts of amidin produce above a hundred and ten grains of sugar. When a two-thousandth of its weight of diastase is maintained for a few hours, at not lower than 150° nor above 175° F., its solution is entirely converted into sugar and gum, without any perceptible escape or change in the whole means that have been admitted. This formation, however, is neutralized by the presence of tannin, though not by alkaline and earthy carbonates. The sugar produced has acquired the new property of fermenting with yeast to form alcohol; and the gum, itself insoluble in alcohol, by being boiled in four times its weight of water, and acidulated with a hundredth of sulphuric acid, is capable of being converted also into sugar. In all these cases, the sugar yielded is that known as grape-sugar.

As a necessary supplement to the history of starch, let us proceed to trace the principle already referred to as developed during the germination of plants; for it does not exist in them previously to that period. It was discovered by MM. Payen and Persoz (Ann. Sc. Nat. Serié 2, Bot. x. 165), and named by them diastase (διΐστημι, to separate), from its effects in detaching the starch globules from one another. It is to be met with in a natural state, surrounding the insertion of the buds of potato, or of the points of the roots into the tubercles, but not in the roots proper, nor in the shoots. It is also to be met with, in a similar position, in Tall Ailanthus, and in the vicinity of most of the masses of fecula which are accumulated in plants for the development of buds. It is, in fact, produced in small quantity at the base of every sprouting germ, and by its action the fecula is rendered soluble, so as to be conveyed in a state of transition to the parts requiring its supply. It is to be found in wheat and oats; but the favourite source from which it is procured is malted barley, during the change which the starchy matter of the grain undergoes by conversion into sugar. In distillation we only imitate by art what takes place in the living vegetable; but when moist barley has been made to shoot by being exposed to a temperature between 60° and 80°, diastase has effected two important changes—the first to rupture the starch globules, which renders the grain capable of being reduced into a pulp with half its weight of water under a gentle heat; and the second, to convert the whole of the starchy contents into sugar and gum. Sulphuric acid, as before mentioned, produces a similar conversion into sugar, not only of starch, but each of the protein compounds in common. But while diastase is totally inert with regard to these, and indeed exercises no chemical action on gum or any of the vegetable proximate principles, with the exception mentioned, its action on starch is sixty times greater than that of sulphuric acid on the same substance in an equal time. Einhof found, among other results, the flour of barley in its rough state to be composed of 67·2 (?) per cent. of starch, 5·2 of uncrystallized sugar, and 4·6 of gum, with a quantity of gluten, albumen, woody and earthy matter, and water; but, according to Proust, the change induced by malting has increased the gum from 4 per cent. before germination to 15 per cent. after, the sugar from 5 before to 15 after, and the starch from 32 before to 56 after, while the bran, by parting with its attached granules, has been diminished from 55 to 12 per cent. The change is observed to reach its maximum with the least loss of material, when the young growth has attained a size above the grain itself, and the vitality of both seed and plant is then destroyed, by suddenly raising the temperature to 160°. At this point, whether by the action of malt, sulphuric acid, or long boiling, the starch has become thin and limpid, and takes the name of dextrin, from causing the plane of a polarized ray of light to deviate to the right hand. It is amidin at a particular stage of its conversion, made impure with variable proportions of sugar and gum. Dumas gives its composition as similar to starch under the formula $C^{24}\ H^{10}\ O^{10}$. If the ebullition be continued after dextrin is formed, it becomes converted, with great readiness, into grape-sugar; but an infusion of it, if subjected to the action of yeast at the former temperature of between 60° and 80°, becomes fermented, disengaging carbonic acid, and forming alcohol. The sugar of the altered starch impregnates with alcohol the different kinds of beer, ale, and porter which, with the conjunction of hops and other ingredients, are produced on the same principle, the gum of the starch being the cause of the frothy top which distinguishes these from vinous liquors. Diastase is precipitated when ground malt is moistened with half its weight of cold water, the expressed liquid then mixed with enough of rectified spirit to destroy its viscosity, filtering, and then adding spirit freely, after which it will be further purified by three successive solutions in water and precipitations by spirit, and at last dried in thin layers upon glass, at a temperature between 104° and 122° F. When thus treated, it assumes the appearance of a white tasteless powder, not crystalline, soluble in water, but insoluble in alcohol unless it be weak. It acquires acidity by keeping, and its watery solution does not henceforth allow of precipitation, like that of starch by lime, baryta, or diacetate of lead. Common malt is stated, in general, not to contain more than 1-500th of its weight of this principle, and its property in relation to starch thickened with water will always be remarkable, that at a temperature of about 160°, in the minute proportion of a 2000th part of the starch, it occasions, in a few minutes, the bursting of the globules, and more gradually converts the starch into sugar and gum, without loss of weight in the materials employed.

INORGANIC CHEMISTRY.

CHAPTER VIII.

TOXICOLOGY.

Among the many applications of chemical science to the various requirements of society, toxicology, or the detection of poisons, is certainly not the least valuable, and has attained, of late years, a degree of certainty which bids fair to extirpate that cold-blooded and dastardly phase of crime against which it is directed. Thus nobly does science vindicate herself from the aspersions of certain sentimentalists, who profess to behold, in the progress of modern discovery, only an extension of the resources at the command of the vicious. How, whilst the electric telegraph tracks, or rather anticipates, the flight of the robber or assassin—whilst the daguerreotype preserves a faithful record of the features of every man* who has stood before the bar of justice—whilst the tube of Marsh can bring damning evidence against the murderer, even out of the grave of his victim, rational beings can still uphold such views is to us a mystery. Granted that cases of poisoning are still fearfully common, where is the evidence to prove that they have become more numerous, though, from the increase of chemical and medical skill, they are more commonly detected? In olden times, the man who yielded to the administration of arsenic or some other corrosive poison, was supposed to have died of some internal inflammation, and so the matter rested. Granted that chemistry has made us acquainted with certain poisons of a most fearful virulence: these are for the most part rare, expensive, difficult to prepare, and less easily administered to any person, without his knowledge and against his will, than the crude materials whence they are extracted. Who, for instance, would partake of food into which strychnia or nicotina had been introduced? And though manufactures require the use of some extremely noxious bodies, and thus render the latter somewhat accessible, we should do well to remember what vast stores of poisonous matter nature offers to the evil-disposed. The compounds of baryta, arsenic, antimony, lead, form, we might almost say, entire mountains. Every hedge, every grove, even in our own climate, has its supply of noxious plants. And these deadly materials were amply availed for the worst purposes by empirical art, long before science investigated their nature. The classical student well knows to what perfection the horrid trade of poisoning was brought by a Canidia or a Locusta in ancient Rome. The

* In some parts of Switzerland.

manna of St. Nicholas,* used in the middle ages, is still a mystery of fearful interest. The Obiah men of Guinea, and the sorcerers of other equally savage nations, have at their command means of destruction, probably more formidable than all which the resources of European science can supply. Nay, what need we more than simply call attention to the many kings and other eminent personages in times past, whose lives were cut short in this manner, in order to disprove the libellous accusation? On the contrary, the means of detection are becoming daily more perfect. Scarcely is a new poison known to be in vogue, when an accurate test is laid down for its discovery, and it is only in those rare cases where no suspicion is excited, that the guilty may hope to escape. Poisons are, for the most part, either of mineral or vegetable origin, the latter being in general by far the more formidable—a circumstance which throws a strange light upon those quacks who recommend their pills as "containing no mineral ingredient, and being, *therefore*, perfectly harmless." The animal kingdom affords scarcely any instance of a substance which proves fatal when introduced into the stomach.† The poisons of serpents, though extremely destructive if they enter a blood-vessel, are harmless in the stomach.

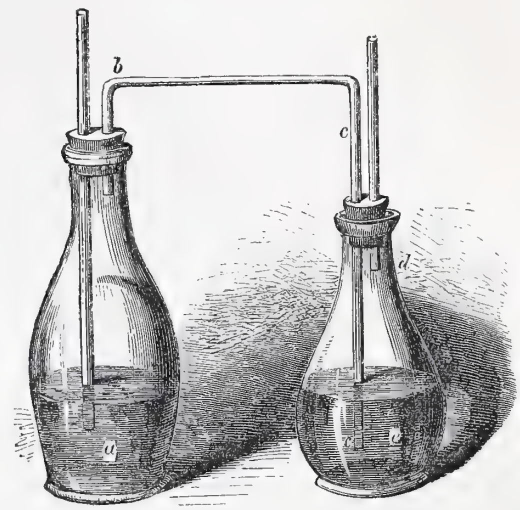
As regards their effects upon the system, poisons are commonly divided into three classes—irritants, narcotics, and narcotico-acrids. To the former belong the majority of mineral poisons; to the second, opium, foxglove, &c.; and to the third, strychnia and various other organic alkalies.

Though in some respects a digression from the object of this article, which is *chemical*, not medical, we will briefly mention the symptoms by which the first effects of poison may be distinguished from an ordinary attack of illness—information the more valuable, since, in cases of this nature, time is everything. If a person, previously in his usual state of health, is attacked, soon after partaking of food and drink, with violent symptoms of disease, which come on suddenly without any previous warning, and increase in violence without any periods of remission, the presence of poison may be, at least, suspected. If, in addition, the patient complains of burning heat in the throat and stomach, redness and swelling of the mouth and tongue, and if a painful sensation of tenderness is experienced in the upper part of the stomach, the probability is greatly heightened. These symptoms, it must be remarked, apply chiefly to the irritant or mineral poisons administered in large doses. If administered gradually, the results are very different: the system slowly yields in a manner not readily distinguishable from the results of chronic illness, and the real nature of the case is, perhaps, never suspected. The vegetable alkalies often act with such extreme rapidity as to render medical aid impossible.

To discover whether a poison has been administered, and if so, to detect its nature, we examine—1. The remnant of any food or drink of which the patient has partaken shortly before the attack. 2. All matter vomited during the time of illness. If it has fallen upon the floor or articles of furniture, the spots should be carefully scraped up, and the matter thus collected deposited in a clean bottle. Portions of clothes, bedding, &c., saturated with the matter vomited, are cut off, treated with distilled water, and the liquid reserved for examination. 3. If neither remnants nor evacuations exist, and if death has supervened, the body is opened, and the stomach, liver, and bowels taken out, and placed in a clean jar.

The first step is now to examine with a lens the substances passed in the vomits or stools, the matter found in the digestive canal, and the mucous surface of the canal itself. In this manner valuable indications may be found, and sometimes solid particles of the poisonous substance discovered in the digestive canal, and especially in the folds of the mucous membrane. Any such particles are carefully removed, and analyzed in the ordinary manner. Should none such exist, the case is much more complicated, since the effect of the common tests, without due preparation, would be entirely masked by the organic matter present. The following is a general process which may be followed with advantage where a corrosive mineral poison is indicated, and which serves to detect arsenic, antimony, mercury, copper, lead, tin, zinc, silver. The matter is cut into fragments with very clean scissors; about 7 oz. are then placed in a glass flask, fig. 1, with one-half its weight of pure concentrated

Fig. 1.



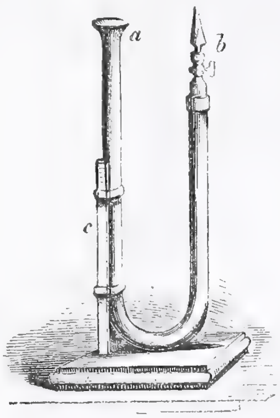
hydrochloric acid. To the neck of the flask is fitted a cork pierced with two holes, of which the one receives a tube 20 inches in length, and $\frac{3}{8}$ of an inch in inside diameter, dipping an inch into the hydrochloric acid, *a*. From the other opening rises a tube bent twice at right angles, *b*, of which the second vertical branch, *c*, plunges through a cork into distilled water in a second vessel, *d*. The same cork is pierced with another hole, in order to receive a straight tube which does not plunge into the water, *e*. The apparatus thus arranged is placed on a sand-bath, and the receiver in a vessel of cold water, which is changed from time to time; the sand-bath is kept at a temperature near the boiling point of the liquid, without, however, reaching it, for four hours, the contents of the flask being stirred from time to time. The organic matter gradually dissolves in the hydrochloric acid, and at length forms a dense, uniform, more or less dark liquid. Remove the sand-bath, and place the flask on the naked fire, and boil the liquid for two or three minutes. Then introduce gradually fragments of chlorate of potash at *a*, shaking the flask frequently, until 16 to 18 parts have been introduced for every 100 parts of the mixture. The liquid becomes clear and yellow, smelling strongly of chlorine, and small fragments of carbonaceous matter, and of a resin-like body, float on the surface. Allow the apparatus to cool, filter the liquid, wash the filter, add the washings and the liquid in the second receiver. Pass a current of well-washed sulphuretted hydrogen through it for some time, and allow it to remain until next day in a closed bottle. In every case there will be formed a precipitate, in which all the above metals may be sought except silver and zinc. The precipitate may, nevertheless, contain merely sulphur and a little organic matter, which may be disposed of as follows. Throw the precipitate on a filter without folds, wash with distilled water, and put it into a small flask with its weight of pure fuming hydrochloric acid; boil and add a few fragments of chlorate of potash; when the reaction is over, add a small quantity of distilled water, and heat cautiously, to expel free chlorine. Filter again, and thus a clear, almost colourless liquid will be obtained, in which arsenic, antimony, mercury, copper, lead, and tin must be sought. The zinc not being precipitable by sulphuretted hydrogen, remains in the liquid. Silver, if present, will be found as an insoluble chloride in the first filter. Arsenic and antimony are now sought for in the clear liquid last obtained, by means of Marsh's apparatus. This important instrument is shown in fig. 2, where *a* is a U-shaped tube made of stout glass; *b*, a stop-cock and gas-jet fixed to its shorter limb; and *c*, a wooden stand supporting the whole.

* Perhaps *meconiate of soda*.—See Sertuerner.

† Cantharidine is, perhaps, the only fully authenticated instance.

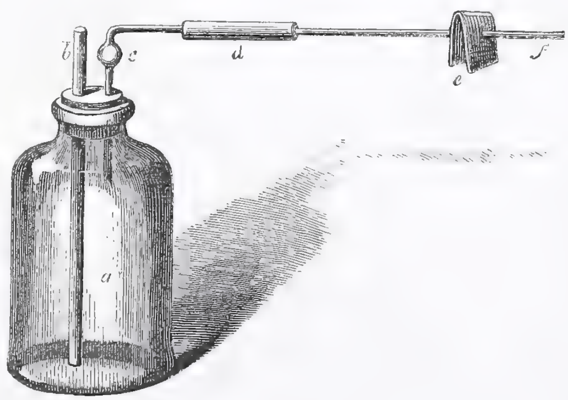
The method of using it is as follows:—Dilute sulphuric acid, previously ascertained to be perfectly free from arsenic, is poured into the tube; the liquid suspected is next added, and a small piece of zinc, whose freedom from arsenic must likewise first be ascertained, is suspended by a waxed thread, and allowed to hang down nearly to the bottom of the shorter limb of the tube, the thread being secured in its place by the cork in which the stop-cock is inserted. Arseniuretted hydrogen gas is immediately generated in the tube, and is allowed to escape until all atmospheric air is expelled. The stop-cock is now closed, when the gas, of course, accumulates in the shorter limb, forcing the liquid up into the other. On opening the stop-cock and applying a light to the jet, the gas ignites and burns with a pale bluish flame. If a fragment of white porcelain be now placed over the flame, so as rather to depress it, a brownish spot of metallic arsenic will be deposited upon it, if that substance was present in the liquid to be tested. It was at first hoped that this result would have been singly decisive. From subsequent researches, however, it appears that antimony, and sometimes even iron, and traces of organic matter, may produce circular spots not easily distinguishable from those due to arsenic, especially if the latter be a mere trace. To remedy this evil, two various processes have been suggested; the one consisting in a modification of the apparatus, the other in a variety of tests applied to the spots.

Fig. 2.



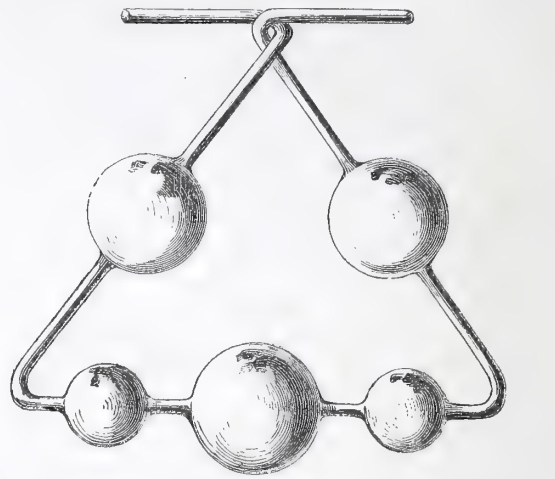
The modification of the apparatus suggested by Liebig and Berzelius, and further improved by several other chemists, is shown in fig. 3. *a* is a wide-mouthed flask, closed with a cork

Fig. 3.



perforated with two holes. Through one of these is passed a a straight tube, *b*, extending to the bottom of the flask, and $\frac{4}{10}$ths of an inch in diameter; in the other hole is fixed another tube, *c*, of smaller bore, bent at right angles, and luted to a wider tube, *d*, about ten inches long, and filled with asbestos. To its extremity is fixed another tube of hard Bohemian glass, about $\frac{1}{8}$th of an inch in diameter, 18 inches or 2 feet long, drawn out to a fine point at the end, *f*, and wrapped in thin leaf copper for $\frac{1}{3}$d of its length. The flask, *a*, must be of such a size as to contain all the liquid in question, and yet leave about $\frac{1}{5}$th of its capacity empty. It has been found advantageous to reduce the liquid to a small bulk of gentle evaporation. The lower end of the tube, *c*, where it dips into the flask, *a*, should be cut in a slanting direction. When all is thus arranged, a few slips of pure zinc are placed in the flask, *a*, along with water enough to rise above the entrance to the tube, *b*, and sulphuric acid is then added. The hydrogen gas evolved expels atmospheric air from the apparatus. The part of the tube wrapped in sheet-copper is next brought to a red heat by means of charcoal in a stout wire grate, or a series of gas-burners. The liquid in question is then introduced through *b*, by means of a small funnel, allowing it to flow down the sides of the tube, so as not

Fig. 4.



to drive any air into the vessel. Should the disengagement of gas cease after its introduction, a fresh supply of sulphuric acid must be added. If arsenic is present, a metallic ring appears at a short distance from the heated part of the tube. The following considerations serve to distinguish between arsenic and antimony. The former is volatile, and may be driven up and down the tube by the application of heat; the latter remains stationary. On heating the tube, previously cut off and held in a slanting position, the former is converted into a white volatile powder (arsenious acid); the latter yields a powder much less volatile. By aid of a little nitric acid, the substance may be dissolved out of the tube, and submitted, in solution, to the ordinary tests.

The following mode of concentrating the suspected liquid, has been proposed by Lassaigne:—

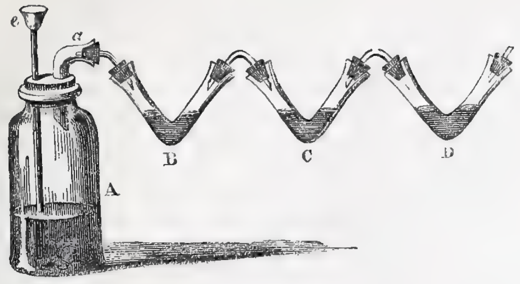
The arseniuretted hydrogen gas, as developed from a Marsh's tube, is not inflamed, but passed into a perfectly neutral solution of nitrate of silver, contained either in a beaker glass, or in a Liebig's bulb-tube (fig. 4). The gas decomposes the nitrate of silver; metallic silver is deposited, and arsenious acid remains in solution, which may be tested, either by a repeated use of Marsh's apparatus, or in other manners.

This process has been modified by Professor Clarke, so as to dispense with the previous decomposition of the organic matter by which the poison was accompanied. *a* (fig. 5) represents a gas-generating bottle, so large that the frothing which ensues in presence of organic matter may cause no inconvenience; it is charged with pure zinc and muriatic acid, not stronger than 1·031. The three tube receivers, *b*, *c*, *d*, into which the gas is successively conducted by the small connecting tubes, shown in the figure, contain, respectively, caustic potash, acetate of lead, and nitrate of silver. As soon as it is found that the hydrogen gas liberated produces no action in the tubes, the liquid in question is introduced at *e*. The arseniuretted hydrogen evolved, deposits in *b* sulphuretted hydrogen and other impurities, which, if they should escape, are arrested in *c*; in *d*, finally, metallic silver is deposited, and the arsenic remains in solution: when all is over, the liquid in *d* is treated with muriatic acid to remove any excess of silver, filtered, and evaporated to dryness. Arsenic acid remains, and may be tested in the ordinary manner.

In the other method, where, instead of modifying the apparatus, we test the spots produced, the following processes may be recommended:—

Lassaigne exposes the spots obtained to the vapour given off by iodine at a temperature of 53°—59° F. By this treatment arsenical spots assume a pale yellowish-brown colour, which becomes lemon-yellow on exposure to the air for a few minutes, and subsequently disappears altogether by continued exposure,

Fig. 5.



or the application of a gentle heat. Antimonial stains, similarly treated, turn a deep reddish yellow, which becomes orange on exposure, and is ultimately permanent. When the yellow arsenical spots have disappeared, if moistened with strong sulphuretted hydrogen water, they are reproduced of a pale lemon-yellow; and vanish anew, if touched with a dilute solution of ammonia. Antimonial iodized stains, after treatment with sulphuretted hydrogen, resist the action of dilute ammonia for a considerable time. Again, an alcoholic solution of iodine dissolves the arsenical spots, and leaves a yellow stain on spontaneous evaporation. Antimonial spots remain unaltered when touched with this solution; but, on spontaneous evaporation, the black stain is replaced by an orange-red one, permanent at a gentle heat; and, on exposure for several days, altered but very slightly. Solution of iodized hydriodic acid behaves in a similar manner, but more energetically. An iodized solution of iodide of potassium instantly dissolves arsenical stains, whilst it does not attack those of antimony.

Slater exposes the stains to the vapour of bromine; those produced by arsenic take a bright lemon-yellow, whilst antimonial stains assume an orange shade. A concentrated solution of iodate of potash turns arsenical spots a cinnamon-red, and dissolves them almost instantly; on antimonial spots, it has no action within three or four hours. A solution of bleaching powder (hypochlorite or chloride of soda) instantly dissolves arsenical stains, leaving those of antimony untouched. (The two last methods are recommended as perfectly decisive.)

There are two other methods of destroying the organic matter present, which it may be well to mention. If the substance suspected is an organic liquid, nitrate of potash is dissolved therein, and the whole evaporated to dryness, stirring all the time, so as to obtain a uniform mass. If pasty or solid, it is cut and bruised in a porcelain mortar with double its weight of nitre, the mixture being thus reduced to a thick paste, in which the nitre is uniformly disseminated, and it is then dried in a porcelain capsule at a gentle heat. A new hessian crucible is now brought to a dark red heat, and into it the organic matter mingled as above is thrown by small portions at a time. If the amount of nitre be sufficient, the residue after combustion should appear white or grey. If it look black, more nitre must be added. The crucible is then withdrawn, and when sufficiently cool, the contents are dissolved out with distilled water. The saline mass or solution is gradually treated with sulphuric acid, to expel all nitric and nitrous acids, evaporated to dryness, redissolved in distilled water, and introduced into Marsh's apparatus.

Otherwise, the substance intended for examination is cut into small pieces, which are placed in a porcelain capsule and drenched with ⅙th or ¼th their weight of pure concentrated sulphuric acid. The fresher the animal matter is, the larger must be the amount of sulphuric acid employed. The capsule is now placed on the fire, when the organic is converted into a half liquid black mass, which must be continually stirred with a glass rod. The heat requires careful management, to prevent succussion and loss. For this purpose a wide shallow capsule should be selected, and pieces of burning charcoal be placed round the edges, that it may not be heated from the bottom alone. When all fear of boiling over is at an end, the heat is raised until the liquid is entirely driven off. The remaining charcoal should be dry and brittle; if tough and greasy, it must, when cool, be treated with a fresh amount of sulphuric acid. The charcoal, when in a proper state, is pulverized and drenched with pure concentrated aqua regia, consisting of 3 parts nitric and 1 part muriatic acid. Heat is again applied, stirring continually until the charcoal is dry. In this state it is extracted with boiling water, and the liquid, which is clear and often colourless, is ready for use in Marsh's apparatus.

The following method of preparing pure zinc may be useful to those engaged in such researches. Common zinc is melted and thrown into a deep vessel of water. When thus granulated, it is reduced to smaller fragments in a mortar, and then placed in a hessian crucible in alternate layers with ¼th its weight of coarsely-powdered nitre, beginning with a layer of nitre, and finishing with one of zinc. The crucible is then ignited until deflagration takes place. When this is over, the dross is removed, and the remaining zinc is perfectly pure.

Reinsch's test.—Into the liquid suspected to contain arsenic a large amount of hydrochloric acid is poured, and a bar of perfectly bright clean copper placed in the liquid, and boiled for 8 to 10 minutes, when the copper will be found coated with metallic arsenic. If the copper is left for a short time in the hot liquid, the arsenic becomes detached, and may be recognised as such by the odour which the detached particles evolve when heated. If the coating is very thin, the bar is withdrawn and washed with nitric acid until it resumes its natural colour, and the washings put into a very small Marsh's apparatus. This method, though suitable when the quantity of material and the proportion of arsenic are large, is less delicate than that of Marsh.

The detection of antimony has been incidentally explained in treating of arsenic.

For mercury, the animal matter, &c., may either be prepared according to the general method stated at the beginning of this section, and the ordinary process of analysis then applied, or a part of the body (the liver by preference, where any poison taken into the system is very apt to accumulate) is treated with concentrated sulphuric acid at 212° F., until all is dissolved. When all is cool, chloride of lime is added, the whole stirred with a glass rod, and water poured in by degrees as the mixture becomes thick and white. The operation is continued until a part yields, on filtration, a colourless liquid. In general, as much chloride of lime is needed as is equal in quantity to the sulphuric acid. The mass is now moistened with cold absolute alcohol, afterwards with water, and filtered, and the residue washed many times with water. In this liquid the mercury is precipitated by inserting a plate of gold, and touching it below the surface with a piece of iron. The mercury is then separated from the gold by distillation. This method, however, fails to distinguish whether the mercury was present as calomel, or as corrosive sublimate.

Or a portion of the substance in question, whether solid or liquid (if the latter, concentrated as far as possible), is laid upon a clean bright copper plate, a strong solution of iodide of potassium being added. If mercury is present, a silvery stain is formed upon the copper.

Mercury may likewise be withdrawn from any organic liquid by acidulating with muriatic acid, and inserting a bright plate of copper, upon which it is then deposited. Or the liquid may be acidulated with a trace of muriatic acid, and a gold wire twisted round a piece of tin-foil plunged under the surface. The gold, in course of time, becomes whitened over with mercury; it may now be digested in concentrated hydrochloric acid, and if the white colour remain unaltered, the gold wire is placed in a narrow tube and heated, when the mercury is driven off. If salts of mercury are contained in solid or semi-fluid organic matter, we may try whether they are soluble in ammonia. From such a solution the mercury may likewise be separated by precipitation upon copper with great exactness.

This is the best method for detecting the presence of mercury in blood, since all the constituents of blood are soluble in ammonia. Where this process is not applicable, the substance is mixed with ⅓d or ¼th its weight of an alkaline carbonate, and placed in a retort, which is fitted nearly air-tight into a receiver. The temperature is gradually raised untii the bottom of the retort is red hot; when the operation is over, the neck of the retort is cut off and split open, and the contents examined for globules of mercury with the help of a lens. If none is to be found, the fragments of glass, with the oil adhering to them, are digested in nitric acid, and the solution thus obtained tested for mercury in the ordinary manner.

Copper may be detected in organic liquids by acidifying a large quantity of the liquid in question, placing it in an evaporating dish, and immersing in it a piece of platinum foil, surrounded by a small zinc plate. The copper is deposited on the platinum, colouring it red, and may be easily removed by nitric acid. Solid or pasty organic substances may be digested in dilute nitric acid, and testing the liquid. Or the mass is mixed with carbonate of soda, ignited in a hessian crucible, pulverized, and the charcoal washed away, when the reduced copper will remain behind. Or the substance is diluted with water enough to form a paste, to which double the weight of crystallized carbonate of soda is added in fine powder. The whole is then placed in a hessian crucible, the cover put on and the temperature raised gradually, maintaining it at a low red heat for a quarter of an hour. The mass, when cool, is powdered in an agate mortar by degrees, adding water gradually, and pouring off the liquid until small metallic spangles remain behind.

A similar process may be applied to lead, although, except when in very small quantities, it is perfectly capable of precipitation from organic liquids by means of sulphuric acid. Solid bodies supposed to contain it may be extracted with nitric acid. Lead and copper, as well as zinc, tin, and silver, may likewise be conveniently sought for in the ordinary manner, after preparing the substance as directed in the outset of this section.

Chromium and its compounds have only recently been employed as poisons. The remnants of suspected food, matter vomited, or after death, the intestinal canal and its contents are carefully examined, their action on reagents observed, and they are then filtered through a fine sieve; the solid part left on the cloth is washed, and the liquid obtained tested with salts of bismuth, lead, silver, and mercury; it is then evaporated to dryness, the residue mixed with an excess of nitrate of potash, the mixture thrown in separate portions into a red-hot platinum crucible; the organic matter is likewise burnt, and a mass of inorganic salts remains. The product thus obtained is taken up with distilled water, which holds in solution alkaline salts, carbonates, nitrates, nitrites, chromates, and sulphates. By adding alcohol and hydrochloric acid by degrees, at a temperature of 122°—140° F., this liquor, which at first is yellow, changes to a light green, and if treated with ammonia, a dirty green precipitate is produced. To ascertain whether this precipitate is really chromic oxide, it is thrown on a filter, carefully washed and dried, and tested with the blowpipe. It may be added, that in some experiments undertaken to decide concerning the poisonous nature of bichromate of potash, ¼ grain proved fatal to moderate-sized dogs in periods of two to six days. From its exceedingly nauseous taste and intense orange-red colour, however, it could rarely be administered without creating suspicion.

Baryta may be detected in organic substances as follows:—If the bodies are soluble in water, they are treated therewith, slightly acidulated with nitric acid; the liquid is then filtered, and dilute sulphuric acid added. If the substances are insoluble in water, they are treated with sulphuric acid, and then heated in a hessian crucible until the carbon of the organic matter reacts upon the sulphate of baryta, and converts it into sulphide of barium. When cool, the mass is boiled with water, filtered, the liquid decomposed with hydrochloric acid, and then tested with dilute sulphuric acid.

The other metals, though for the most part poisonous, are less abundant, and hence less frequently employed with malicious intention. The detection of vegetable poisons, such as the organic alkalies, is more difficult, both from their peculiar nature and from the smallness of the dose required; still, of late years, rapid advance has been made towards the solution of this important problem, and, as regards some of the more common and more formidable of these bodies, very satisfactory results have been already attained.

Strychnia.—The ordinary test for strychnia is as follows:—Place a drop of strong sulphuric acid on a piece of glass, add to it a particle of the suspected substance, and stir the whole together so as to promote solution. Then sprinkle over the mixture a little powdered bichromate of potash, and draw a glass rod through the solution. If strychnia be present, a beautiful violet tint will appear, which after a few minutes will fade into reddish-yellow. This test suffices to distinguish strychnia from morphia, brucia, aconita, atropia, codia, narcotina, picrotoxia, cinchonia, quinia, solania, veratria, and phloridzia.

Marchand rubs the suspected substance with peroxide of lead and concentrated sulphuric acid, to which 1 per cent. of nitric acid has been added. If strychnia be present, the mass turns blue, then violet, then red, and after some hours a delicate yellow. To separate strychnia from organic matter, the whole should be digested at a very gentle heat with animal charcoal, and allowed to stand for about 24 hours; at the end of this period the charcoal is withdrawn, boiled in four times its weight of ordinary alcohol, filtered and distilled, a watery liquid, holding the strychnia (if any) in solution, remains behind. A few drops of potash are then added, and the whole shaken up with ether. The ethereal solution, evaporated upon a watch-glass, leaves the strychnia comparatively pure. E. W. Davy proceeds as follows:—A little of the suspected substance is moistened with a drop of concentrated sulphuric acid; then a little ferridcyanide of potassium is added, either in powder, or as a strong solution, when a fine deep violet colour is produced, which slowly passes into a light brick-red. This test is comparatively little affected by the presence of alcohol and sugar.

Crude *opium* may be detected as follows:—The substance in question is agitated in ether, a little potash having been added; a piece of unsized paper is dipped several times in the ethereal solution, allowing it to dry between each immersion. It is then moistened with dilute hydrochloric acid, and exposed to the vapour of boiling water, when, if opium is present, a red colour is produced.

To recognise the presence of *nicotina* in organic solutions, Herapath treats the fluid in question with a slight excess of caustic potash, and then agitates with chloroform. The latter liquid is carefully removed with a pipette and evaporated to dryness, when the nicotina remains behind, and may be subjected to the following tests. Chloride of gold yields a reddish-yellow precipitate, very soluble in excess of nicotina. Chloride of cobalt, a blue precipitate changing to green: this reaction distinguishes nicotina from ammonia, since an excess of the latter dissolves oxide of cobalt, forming a red solution, which is not the case with nicotina. Its other reactions are very similar to those of ammonia. If it is required to detect nicotina in the body after death, we proceed in the following manner:—The contents of the stomach and intestines, or the organs themselves, are placed in a large quantity of sulphuric ether; after twelve hours' maceration it is filtered, the ether passes through, holding nicotina in solution; but if the matters acted on are fatty, it will contain a soap consisting of nicotina, and one or more fatty acids; perhaps, also, non-saponified nicotina. The ethereal liquid is evaporated almost to dryness at a very gentle heat. The greasy and soapy product obtained rarely shows any alkaline reaction. It is then agitated in the cold, with caustic soda dissolved in water to decompose the soap, and set free the nicotina. The whole is then placed in a retort provided with a receiver, plunged in cold water, and distilled to dryness. The liquid condensed in the receiver contains all, or the greater part, of the nicotina. The retort should be very large in proportion to the quantity of liquid operated upon.

The matter contained in the stomach and intestines, as well as those organs themselves, are macerated in water acidulated with pure sulphuric acid. At the end of twelve hours it is filtered, the liquid, which is generally of a yellow colour, containing sulphate of nicotina and organic matter. It is then

evaporated almost to dryness in a retort and receiver over the water-bath; then treated with a little distilled water, which dissolves the sulphate of nicotina. It is then filtered; the clear liquid mixed with a little pure soda or potash, in order to saturate the acid, and set free the nicotina. The mixture of nicotina and alkaline sulphate is next put into a retort and distilled to dryness, and the distilled liquid evaporated in the water-bath, in order to concentrate the solution of nicotina. Or, instead of distilling the liquor, it may be treated with ether, which, when decanted and allowed to evaporate, leaves nicotina.

Or if the digestive canal be treated with absolute alcohol, containing a little soda, nicotina, if present, is dissolved, and by the reaction of the soda, a soap is formed with the fatty matters which sets free the nicotina, which has then only to be distilled after evaporation to dryness. In a similar manner the poison, if already absorbed, may be detected in the liver. Its presence in vegetable infusions may be thus ascertained. The liquid in question is treated with an excess of caustic potash, and then agitated with a little chloroform. The latter is then withdrawn by means of a pipette, and evaporated to dryness, when nicotina is left behind.

The following general process is applicable in almost all cases where poisoning by an organic alkali is suspected. To the matter in question (portions of liver, stomach, contents of intestinal canal, &c.,) is added twice their weight of pure and very strong alcohol; according to the nature and quantity of the matter, we next add from 10 to 30 grains of tartaric or oxalic acid, by preference the former. The mixture is then introduced into a flask, and heated to 160° or 170° F.; when cool it is filtered, the insoluble residue washed with strong alcohol, and the clear liquid evaporated under the air-pump. If, after the alcohol has evaporated, the residue contains fatty or other insoluble matters, the liquid is filtered a second time, and then the filtrate and washings of the filter evaporated under the air-pump till nearly dry. The residue is then exhausted with cold absolute alcohol, and the liquid thus obtained evaporated under the air-pump; the acid residue is dissolved in the smallest possible quantity of water, and the solution placed in a test-tube, and pure bicarbonate of soda in fine powder added by degrees, as long as any effervescence arises. The whole is then agitated with four or five times its bulk of pure alcohol, and left to settle. When the ether floating on the top is perfectly clear, some of it is decanted into a capsule, and left to spontaneous evaporation. Two cases are now possible:—

1. *The alkali is liquid and volatile.* In such a case, on evaporating the ether, there remain in the capsule small liquid striæ, which fall to the bottom of the vessel. Under influence of the heat of the hand, the contents of the capsule give off an odour more or less unpleasant, which beomes pungent, suffocating, or irritant. If so, to the contents of the vessel from which this specimen was withdrawn, we add 1 or 2 fluid drms. of a strong solution of potash, and agitate the mixture. After a sufficient time, we draw off the ether into a test-tube, exhaust the original mixture by two or three successive treatments with ether, and unite all the ethereal fluids. We pour into this ether, holding the alkaloid in solution, 1 or 2 drms. of water, acidulated with $\frac{1}{5}$th of pure sulphuric acid; agitate for some time, leave it to settle, pour off the ether floating at top, and wash the acid liquid at the bottom with a new quantity of ether. As the sulphates of ammonia, nicotina, anilina, quinolea, picolea, and petinia are totally insoluble in ether, the acidulated water contains the alkaloid in small bulk, and in the state of a pure sulphate, but as the sulphate of conia is soluble in ether, a small quantity of it may remain in that liquid. The ether retains all the animal matter which it has taken from the alkaline solutions. If it, on spontaneous evaporation, leaves a small quantity of a feebly yellow-coloured residue of a repulsive animal odour, mixed with a certain quantity of sulphate of conia, this alkaloid exists in the matter under analysis. To extract the alkaloid from the solution of the acid sulphate, we add to the latter a concentrated aqueous solution of potash or soda; we agitate and exhaust the mixture with pure ether; the ether dissolves ammonia, and the alkaloid is now free. We allow the ethereal solution to evaporate at the lowest temperature possible; almost all the ammonia escapes with the ether, whilst the alkaloid remains as residue. To eliminate the last traces of ammonia, we place for a few minutes the vessel containing the alkaloid in a vacuum over sulphuric acid, and obtain the alkaloid with its peculiar chemical and physical characters.

2. *The alkaloid is fixed and solid.* In this case it may happen that the evaporation of the ether resulting from the treatment of the acid matter, to which we have added bicarbonate of soda, may or may not leave a residue containing an alkaloid. If it does, we add a solution of potash or soda to the liquid, and agitate it briskly with ether. On evaporation of the ether, the alkaloid remains on the side of the capsule as a solid body, or, more commonly, as a colourless milky liquid, holding solid matter in suspension. The odour is disagreeable, but not pungent; it turns red litmus a permanent blue. The next thing is, if possible, to obtain the alkaloid in a crystalline state, so as to determine its form. Put some drops of alcohol in the capsule containing the alkaloid, and leave it to spontaneous evaporation. It is, however, very rare that the alkaloid, as thus obtained, is pure enough to crystallize. Almost always it is contaminated by foreign substances. To isolate these, some drops of water, feebly acidulated with sulphuric acid, are poured into the capsule and then moved over its surface, so as to bring it in contact with the contents. Generally, the acid does not moisten the sides of the vessel. The contents separate into two parts: one formed of greasy matter, which remains adherent to the sides; the other alkaline, which dissolves and forms an acid sulphate. We cautiously decant the acid liquid, which, if the process has been well conducted, is limpid and colourless; the capsule is well washed with some drops of acidulated water, which is added to the first liquid, and the whole is evaporated to three-fourths under the air-pump. To the residue is added a very concentrated solution of pure carbonate of potash, and the whole treated with absolute alcohol, which dissolves the alkaloid, leaving untouched the carbonate of potash and sulphate of potash. The evaporation of the alcohol now leaves the alkaloid in crystals, which, when thus isolated, is readily determined by means of the tests to be mentioned in a subsequent chapter. In this manner may be detected morphia, conia, strychnia, brucia, veratria, emetia, colchica, aconita, atropia, and hyoscyamia.

Hydrocyanic acid.—(*Prussic acid, essence of bitter almonds, &c.*) More abundant than perhaps any of the organic alkalies, and more liable to fall into the hands of ignorant or malicious persons, prussic acid yields nothing in virulence to the bodies we have just been describing. When mixed with any liquid, or if recently swallowed, it may be readily detected by the powerful odour of bitter almonds which it diffuses, but if present in very minute traces, or if already absorbed into the system, a more accurate procedure becomes needful.

The solution is precipitated with nitrate of silver; $\frac{1}{2}$ grain of the cyanide thus obtained is mixed with a little oxide of iron and carbonate of potash, and the whole fused in an iron or platinum crucible. The fused mass is now dissolved in $\frac{1}{2}$ oz. of distilled water, filtered and acidulated with a little hydrochloric acid. The liquid thus obtained is divided into two portions; to the one is added sulphate of copper, and to the other chloride of iron. If prussic acid were present in the original liquid, the former will give a brown and the latter a blue precipitate. It is needless to observe that this test will require some preliminary operations; the liquid in question must be freed from animal matter, since, if nitrogenous substances were entangled, *e. g.*, in a precipitate of chloride of silver, cyanogen might be produced during the fusion, and the same results obtained.

Another process is as follows:—Add one drop of persulphuret of ammonia to the suspected liquid in a watch-glass, and apply heat until the mixture is perfectly colourless. If prussic acid was present, sulphocyanide of iron will have been formed, which will give with persalts of iron a deep blood-red tinge.

A transformation of this kind is, it appears, spontaneously effected after death, in the bodies of animals poisoned with prussic acid. To turn this circumstance to account, the heart, with as much of the blood as can be collected, is separated from the dead body. The latter, with the washings of the former, are carefully evaporated to dryness in a porcelain dish.

The brittle mass thus obtained is reduced to a fine powder, and boiled with some strong alcohol, and a little pure and recently ignited ivory black. The alcoholic solution resulting from this operation is afterwards filtered and evaporated to dryness, the dry residue treated with a few drops of water, the solution acidulated with a trace of pure hydrochloric acid, and tested with perchloride of iron, so highly dilute as to be almost colourless. A blood-red tint will then indicate the presence of sulphocyanogen.

We cannot conclude the present chapter without reminding all chemists of the uncommon degree of care and attention required in all toxicological operations. When called upon by the authorities to give evidence in a case of supposed poisoning, let us ever bear in mind that the slightest error on our part, the impurity of a reagent or the uncleanliness of a vessel, may devote an innocent person to a death of ignominy. Surely, then, the care and precaution which science demands of us in all experiments, are here required under a still higher sanction.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER VII.

Nearly at the same time flourished Arnold de Villanova, a native of Provence, born A.D. 1240. He studied at Barcelona and Paris, became professor at the university of Montpellier, and obtained the highest eminence as a physician, curing several kings, and even the pope. His universal medicine was *water of gold*, the preparation of which is unintelligible. He likewise studied astrology, and came to the conclusion that the world would come to an end in 1335. This embroiled him with the theologians, who probably claimed the sole right of uttering such predictions. He was ordered to quit France as a heretic, notwithstanding the interposition of the pope, and died in 1313. Of his numerous works,* the most important is the *Rosarium*, an epitome of all the alchemical lore of the day. His style is rugged, dry, and purposely obscure. He, too, like Lully, insisted strongly upon distillation; he ascertained the physical and physiological properties of alcohol, and was probably the discoverer of oil of turpentine.

Nicholas Flamel, commonly reported to have been in actual possession of the philosopher's stone, and to have accumulated a great fortune by its means, appears, on careful examination, to have been no chemist at all.

John Isaac Hollandus, and his brother, natives of Stolk in Holland, flourished in the 13th century, subsequently to Villanova, whose writings they quote. They were plain, lucid, honest compilers, chiefly remarkable for having given figures of apparatus in their works, and for having occasionally written in German.

After a century of unceasing but nameless investigators, the world was visited again by a lofty genius. Basil Valentine, the Benedictine monk of Erfurt, was born about 1394. Of his life, little is known, except that he reached the dignity of abbot, and became universally famed for his learning, and, of course, suspected of magic. A vast number of works in Latin and German bear his name, but we must remember that the alchemist-swindlers of the 15th and 16th centuries were in the habit of ascribing their absurd productions to the great alchemist-philosophers of a former age. Basil Valentine is chiefly known from his studies on antimony, a substance, afterwards, in great favour among alchemists. He not only discovered this metal and introduced it into medicine, but ascertained all its properties as far as known at the end of the 18th century. The story goes that, having thrown certain antimonial preparations into the convent-piggery, and observing the inmates become sleeker and plumper in consequence, he was induced to try the effects of the same agent upon his monastic brethren. The result, it is added, was so unsatisfactory, that the metal was called *antimoine*, hostile to monks. But, in the works of Basil Valentine, antimony is called by its German name, *spiessglanz*, which renders the whole story improbable. Our author was a firm believer in transmutation of metals, which he considered as compounded of salt, sulphur, and mercury. Yet a large part of his attention was devoted to researches of a more practical tendency. He studied the compounds of lead, mercury, arsenic, and antimony with much success. He ascertained that glass could be bleached by manganese, and tinged green by oxide of copper. He knew that iron precipitates copper from its solutions, that gold is present in many specimens of silver, and that tin is often contaminated with a trace of iron. These facts have led many to consider him as the father of chemical analysis. To enumerate all the important observations found in his works, would very much exceed our limits.* His labours illustrate the gradual extinction of alchemy. There was no clear, sudden conviction of its futility—no victorious arguments were used against it. Men still believed in transmutation, but their attention was more and more turned towards the valuable substances which they had discovered whilst seeking the philosopher's stone, whilst the original object gradually faded from their view. Alchemy was the seed-leaf of chemical science, which withered away when no longer needed. Basil Valentine concludes an epoch. He is the last of the great philosophic alchemists. In the hands of Paracelsus, the art underwent a decomposition, as we shall point out below. *Goldmakers* we shall indeed meet with during the two next centuries, but they are no longer the ruling spirits of the age, no longer profound thinkers, devout enthusiasts. Some of these latter alchemists were honest, patient, but narrow-minded operators, whose labours were from time to time rewarded by an important discovery. But the majority were mere impostors, without the least faith in their own pretensions. Their custom was to deceive some credulous and wealthy person by a few juggling experiments, that he might be led to advance them money. Operations were then commenced with great pomp, and small particles of gold were occasionally produced, in order to keep alive the faith of their victim, whilst plausible pretexts were never wanting to account for the failure of the grand process.† When either the patience or the means of the dupe was exhausted, the alchemist would blow up his workshop and decamp, to play the same game elsewhere. It is from such impostors, and not from Valentine, Lully, or Roger Bacon, that the alchemists of the drama or of popular tradition have been derived. Nay, until within the last thirty years, men of learning, so styled, having read of fraudulent goldmakers, sought to penetrate no deeper, and utterly overlooked the historical significance of the elder alchemy, and the grand ideas of its cultivators.

During this later period, several successful attempts at transmutation are recorded, all of a decidedly suspicious character. A stranger, in every instance, suddenly makes his appearance in the laboratory of some well-known chemist, performs the experiment, and is afterwards *never more heard of*. This is, especially, to be remembered. That these mysterious strangers did not aim at concealing their (pretended) knowledge of the great art, is plain from the narratives. Why then do we not hear of their subsequent adventures? Further, had the hermetic art been possessed, it would indubitably have been exercised so as to affect the supply of the precious metals. But, during the 17th and 18th centuries, we find no sudden influx of bullion beyond the regular supply obtained from the Spanish colonies. Besides, at that time, just as in our days, no one could grow unaccountably rich, without exciting curiosity,

* An edition in one volume, folio, appeared in Strasburg in 1613.

* The principal works ascribed to Basil are:—Philosophia Occulta; Apocalypsis Chemica; Azoth Philosophorum; Claves XII Philosophiæ; De Microcosmo; Vom grossem Stein der Uraltén; Triumphwagen Antimonii; Licht der Natur, &c.

† The stratagems of these impostors were numerous. Sometimes a thin plate or rod of gold was covered over with iron, lead, or tin. It was then publicly plunged into the pretended transmuting liquor—nitric or sulphuric acid—which dissolved off the covering, and left the precious metal exposed. The adept then proclaimed that he had converted the iron, &c., into gold. Sometimes a crucible was provided with a false bottom, under which was placed gold, silver, or their oxides. The operator, after exhibiting the apparently empty vessel, threw into it some lead, brought it to fusion, and added his "powder of projection." The false bottom being destroyed by the heat, the gold or silver mingled with the lead, and was detected and separated in the usual manner. Sometimes melted lead was stirred with a hollow rod containing oxide of gold. The amount of the precious metal thus produced was of course very trifling, yet it sufficed to keep up the deception.

even perhaps legal investigation. We may, therefore, safely dismiss these stories as apocryphal, the more as they depend not upon the testimony of an eye-witness, but merely upon hearsay. The most noted of these is the Geneva case. Mangetus, not the most critical of writers, relates, on the authority of one Gros, a clergyman, who had himself dabbled in alchemy, that an Italian appeared in that city of watchmakers, and being in want of money, did convert an amalgam of tin and mercury into ingots of the finest gold. Another experiment was performed in the laboratory of Robert Boyle, in whose writings, however, it is nowhere mentioned.

The following formula, given by Mangetus, shows the method of operating followed by the later alchemists:—

1. Prepare a quantity of spirit of wine, so free from water that it is wholly combustible, and so volatile, that a drop let fall evaporates before it reaches the ground. This is the first menstruum.

2. Take pure mercury, shake it up in a glass vessel with common salt and distilled vinegar. Pour off the vinegar if it becomes black, and add a fresh quantity as long as it is discoloured. The mercury is now quite pure and very brilliant.

3. Take of this mercury 4 parts, of sublimed mercury (mercurii meteoresati)—probably corrosive sublimate—8 parts, and grind them up with a wooden mortar and pestle.

4. This mixture is placed in an aludel upon the sand-bath, and gradually heated until the whole sublimes. The sublimation is several times repeated, yielding the *salt of wise men*—calomel with an admixture of corrosive sublimate.

5. Grind it in a wooden mortar, put it in a glass retort, and add No. 1 till it stand three finger-breadths above the powder; seal the retort hermetically, and heat for 74 hours, with frequent shaking, and finally distil at a low heat. Spirit of wine passes over with *spirit of mercury*—(the corrosive sublimate is dissolved). More alcohol is added, and the process repeated, until all the salt is dissolved. (This is unintelligible, since calomel is insoluble in alcohol.)

6. Take this mercurial spirit, containing our magical steel in its belly, put it into a glass retort, and distil at a very gentle heat. There will remain the quintessence or soul of mercury. This is sublimed by a stronger heat, and preserved for further use. This is our luna, our fountain, in which the king and queen may bathe.

7. In the name of God, then take common gold, purified in the usual way by antimony, convert it into small grains, which must be washed with salt and vinegar till it be quite pure. Take one part of this gold, and pour on it three parts of the quintessence of mercury; as philosophers reckon from 7 to 10, so we also reckon our number as philosophical, and we begin with 3 and 1. Let them be married together like husband and wife, to produce children of their own kind, and you will see the common gold sink and plainly dissolve. Now the marriage is consummated, now two are converted into one; thus the philosophical sulphur is at hand, as say the wise; *the sulphur being dissolved, the stone is at hand.* Take then, in the name of God, our philosophical vessel, in which the king and queen embrace each other as in a chamber, and leave it till the water is converted into earth, then peace is concluded between the water and the fire.

8. Take of our sulphur one part, and project it upon three parts of very pure gold fused in a furnace; you will see the gold converted into red sulphur; take one part of this, and project it upon three parts of fused gold, and one part of this is again mixed with three parts of gold. Now the sulphur will be sufficiently fermented.

9. Take of the fermented sulphur one part, and project it upon ten parts of mercury heated in a crucible, and you will have perfect gold.

This recipe, which we have stripped of much unnecessary verbiage, commences intelligibly, but ends in perfect mysticism.

Besides the fraudulent quacks, who, under the name of gold-makers, infested Europe for some centuries—life-pill making not being as yet fashionable—there were not a few honest laborious operators, who, without making profession of any high philosophic faith, made important discoveries. To these men and their researches, as well as to Paracelsus and his school, improperly classed among alchemists, we shall recur in a future chapter.

The distinction between astrology and alchemy on the one hand, and sorcery, necromancy, or witchcraft on the other, we have already pointed out. The latter will require but a brief notice. The fundamental principle of magic is simply this: Primitive man, taking himself for the type of nature, views all things as personal, animated, or as swayed by tutelary genii. Knowing that he himself can be influenced by invocations, entreaties, he applies the same methods when desirous of influencing the outward universe. Hence come spells, charms, incantations. If we inquire why magic was so particularly luxuriant in the middle ages, the cause is plain. The polytheistic religion of antiquity, whether Egyptian, Græco-Roman, or Teutonic, had been overthrown, but not extirpated. Their gods, degraded from the rank of deity, still held in popular opinion an ambiguous position, and were supposed to possess superhuman power. The existence of a divine order in the universe not being generally felt, these beings, together with the demons of Christian revelation, were considered capable of influencing outward physical phenomena, and their aid was frequently invoked to ascertain future events, to discover secrets, to avert sickness, or, on the other hand, to injure and destroy an enemy. We must distinguish between magic in the stricter sense, and witchcraft. The former was taught in universities;* was practised by men of learning, and did not necessarily imperil the souls of its followers. Witchcraft was confined to the rude and illiterate, and consisted in a formal compact between a human being and the devil, in which the former solemnly renounced all claims to eternal salvation, on condition of receiving the aid of the latter whenever required.

The doctrine of the higher magicians, though emanating from the same sources, differed considerably in mode of expression from the popular mythology. Following the old notion of four elements, they assumed four classes of elemental spirits, —sylphs or powers of the air, undines or nixes of water, salamanders of fire, and gnomes or kobolds of the earth. Higher than all these stood the spirit of our world, and higher still, Macrocosmus, the soul of the universe. These beings are not the genii or gods of any religion or mythology, but owe their origin to the personifying philosophy, though some magicians appear to have regarded them as tutelary angels, to whom the oversight of each class of phenomena was divinely committed. In certain cases, however, the aid of evil spirits was *commanded*, not *implored*, the operator making use of the words—"forasmuch as God has committed unto us to bruise the serpent's head; much more, to rule over every unclean spirit." The method of summoning spirits was as follows:—A circle was drawn with holy water, within which stood the necromancer, his assistants, and the spectators. Here was erected an altar, upon which lay an open copy of the scriptures in the original tongues, and a number of consecrated relics. The room was filled with the fumes of fragrant incense, and after a variety of ceremonies, the operator pronounced a long adjuration, commanding the spirits to appear before the circle "in human form, and without hurt to the souls or bodies of those present." The spirits were then supposed to arrive, and answer the questions put to them, not, however, without an amount of quibbling and prevarication that would do credit to an Irish witness. Another method was the use of the mirror or crystal. Distant objects or future events were made to pass in panoramic succession over the surface of what appeared to be a large mirror, or were beheld within a globe of glass or translucent stone. It must be remarked that these incantations, though accompanied with prayers and religious ceremonies, were generally condemned by the church as heathenish and blasphemous. Among the principal practitioners of magic, of whom we have merely a legendary account, stand the names of Cornelius Agrippa of Nettesheim, Nostradamus, and Michael Scott. Many eminent men were, indeed, as we have seen, from popular ignorance or ecclesiastical ill-will, denounced as sorcerers, and not a few alchemists and astrologers believed it necessary to secure the aid of the elemental spirits. We may now ask, what amount of truth do the stories of magic contain?

* As at Padua and Salamanca.

A large proportion of the recorded wonders exhibited by the necromancers of ancient Egypt, Greece, and of mediæval Europe, was doubtless jugglery. This art has been from time immemorial diligently cultivated in Southern Asia as an instrument of deception. The lithe, agile frame of the Arab and Hindoo, peculiarly fits them for sleight of hand exploits. Thence the art appears to have been brought to Europe during the period of the Crusades, and of the Moorish occupancy of Spain. There is nothing tolerably authenticated in the annals of sorcery, more marvellous than the feats exhibited by Houdin, Anderson, Blitz, and their compeers. If the performances of these itinerant conjurors, even in the nineteenth century, and in this our civilized country, seriously unsettle the popular mind, is there any reason to doubt how such achievements would have been regarded eight hundred years ago? The "tregitours" of the middle ages, who travelled about to entertain the knights and nobles with their skill, would produce in a hall the semblance of a battle, a siege, a stream of water with vessels, &c. This must have been done by means of the magic lantern. But, in addition to this avowed jugglery, there were serious believers in magic. Their theory—the doctrine of elemental spirits, and of the animation of all things—we have already stated. On what facts did this theory rest? After every allowance has been made for the imaginative leanings of the pristine world, and for its proneness to hasty theorizing, something must remain. Now, we are not going to admit the apparition of objective spirits. The clue lies, in our opinion, in the process of adjuration. Many drugs, it is now known, when swallowed or inhaled in the state of vapour, powerfully exalt the imagination, and produce visions of phantoms—angels and demons, according to the ideas with which the mind is occupied. Now, the incense used in the magical fumigations, as far as we can ascertain, consisted of drugs of this nature. The spirits seen and conversed with by the magician, were, therefore, essentially subjective—the creation of his own brain under the narcotic action of the incense, and had no more real existence than the fiends seen by the drunkard when labouring under the attack of *delirium tremens*. What powerfully confirms this view is, that when it was desired to dismiss the spirits, other fumigations were employed, containing ingredients which exert a tranquillizing action upon the nervous system.

GEOGRAPHY.

CHAPTER IX.

SUBDIVISIONS OF EUROPE—THE BRITISH EMPIRE.

III.—IRELAND.

Historical Sketch.—The ancient name of Ireland was *Ierne*—from which are derived the names *Juverna*, *Hibernia*, *Erin*, and its modern name *Ireland*, which signifies *Ierneland*. From its being originally peopled, like England and Scotland, by the ancient Celts, the name *Ierne* is believed to be derived from a Celtic root, signifying, according to some writers, the *sacred* isle; according to others, the *western*.

About the beginning of the fifth century, the *Scoti* were the most powerful tribe in Ireland, and, as already mentioned, they gave their name to the island for several centuries. The predecessors of the Scoti seem, at some antecedent period, to have been considerably advanced in civilization; a fact which is amply attested by the cyclopean buildings, sepulchral mounds, containing stone chambers, mines, bronze instruments, and weapons of classic form and elegant workmanship, which still remain as monuments of the mechanical skill, taste, and ingenuity of the ancient inhabitants of Ireland.

Little is known of Ireland historically till the beginning of the fifth century, when its inhabitants were converted to Christianity by its great apostle St. Patrick. This celebrated individual appears to have been born at the place now called Kilpatrick, in Scotland, whence he went to Rome to prosecute his studies for the priesthood. His original name was Maur, but that of Patricius was given him by Pope Celestine, when he consecrated him a bishop, and sent him as a missionary to Ireland, where he landed in the year A.D. 432. The introduction of Christianity was followed by a great advance in civilization; Greek and Roman literature were studied by the clergy; the style of architecture was very much improved by the desire which the general wish to adorn their ecclesiastical edifices inspired; the round towers which exist in Ireland to this day, and which are now believed to have been built for ecclesiastical purposes during the sixth, seventh, and eighth centuries, are a sufficient indication of the advanced state of the country. At this epoch, indeed, and for several centuries after, Ireland was so much distinguished as the seat of learning, as to supply the European universities with many of their professors.

Like every other nation in this barbarous age, Ireland suffered much from foreign invasions. In 845, the Danes, after harassing the country for a considerable period, got possession of almost the whole kingdom; but they were soon after defeated and expelled. The country was also much torn by civil broils between the kings and chiefs from the eighth to the twelfth centuries.

In 1174, Henry II., king of England, took possession of the island, made the native kings and chiefs his vassals, and portioned out the kingdom among his nobles. In the reign of King John, almost the whole of Ireland was divided into counties, and English laws and customs were attempted to be introduced; but this innovation was thwarted by the great barons, who gradually assumed the character of despotic chieftains; so that when Henry VIII. ascended the throne of England, Saxon laws were only recognised in a small tract of country along the eastern coast.

During the latter part of the reign of Henry VIII., and during the succeeding reigns of Elizabeth and James I., the English government, being now Protestant, did everything in its power to effect not only a civil, but a religious reformation in Ireland. Ever since its first establishment by St. Patrick, the Roman Catholic faith had been the faith of Ireland, and at the period of the Protestant Reformation, the doctrines of Luther and Calvin gained no footing there. The English government, however, attempted to effect by force, what all the arts of persuasion had failed to accomplish; and by imposing penal laws of the utmost severity against the Roman Catholic religion, by confiscating the property of that church, as well as much of the property of its adherents, and by acting with the most unheard of severity and harshness towards the former occupants of the soil, they succeeded at length, after stirring up an oppressed people to several justifiable rebellions, in making the whole island shire-ground, in the beginning of the 17th century, and in planting a Protestant proprietary in Ulster.

Rebellions broke out in 1641, in 1689, and in 1798, for recovering their civil and religious liberty; but in these the Irish were unsuccessful, while additional extensive confiscations of property followed, more severe and stringent penal laws against Roman Catholics were from time to time enacted, and more rigorous punishments upon political leaders were inflicted; till, by an Act of Union, the parliament of Ireland, which had been for a considerable period independent of all power but the crown of England, was merged into that of Great Britain in 1800.

This legislative union between Ireland and Great Britain has, ever since its enaction, been looked upon by the great majority of the inhabitants of Ireland, as the chief cause of all the miseries which have afflicted that country; and they believe that a repeal of this union would be productive of the most beneficial results. Whether such would be the case or not, we cannot pretend to determine; but that the conduct of the British government, at the period above alluded to, was sufficient to produce a deep-rooted hatred of the Saxon in the breast of every son of Erin, very few would now attempt to question, who has given that period of the history of the country a moment's calm consideration.

In 1829, mainly by the instrumentality of the late Daniel O'Connell, the Roman Catholics of Ireland were emancipated from many of the penal laws which pressed so heavily upon them; and, in 1832, the Irish Reform Bill passed. In 1838,

a Poor Law was first enacted for Ireland. In 1847, the population was decimated by famine, occasioned by the failure of the potato crop of the previous year.

1. Superficial Features.—The general form of the island has been compared to an oblique parallelogram. The western shore is in general lofty and precipitous, terminating abruptly in the sea from the mountain ranges in the neighbourhood; the south-western coast is much exposed to the fury of the Atlantic, and is therefore deeply indented by arms of the sea jutting in between rocky promontories; the eastern coast is flat and little indented.

The surface of Ireland is diversified by mountains, extensive bogs, lakes, and fertile plains; and although it may be considered as an undulating or hilly country, it is far less rugged than the Highlands of Scotland, and not so tame as the eastern division of England. The central portion of the country is occupied by a vast level, extending from the sea at Dublin to the bay of Galway on the west, and from the counties of Sligo and Fermanagh on the north, to the confines of Cork and Waterford on the south. This plain consists chiefly of cultivated land and extensive bogs, broken here and there by a few undulating hill ranges. It contains the Bog of Allen, a vast morass, about 300 feet above the level of the sea, and the source of several rivers; including this bog, the central plain contains upwards of 1,000,000 acres of bog. The whole extent of bog in Ireland is calculated by Sir R. Kane to occupy 2,830,000 acres, or about a sixth part of its entire surface.

The chief mountain groups are external to this plain, and extend into Wicklow, Tipperary, Limerick, and Kerry on the south; and in the north-east we have a mountain range occupying the southern angle of Down. Towards the north, the counties of Monaghan, Cavan, and Fermanagh are somewhat mountainous; while in the extreme north, Antrim, Londonderry, and Donegal are very mountainous, and in many parts present a rugged and sterile aspect. In the west of the province of Connaught, the mountain ranges are distributed round the coast, the rest of the province being tolerably level.

2. Climate.—Ireland is remarkable for the moisture of its climate, and for its being less liable to severe cold than any of the neighbouring countries. The reason of this being, that the Atlantic ocean extends uninterruptedly round the whole island. Little of the land is more than 50 miles distant from the sea, and its general altitude above the ocean is comparatively slight. As a proof of the mildness of the climate, it is sufficient to remark, that, even in the northern extremity of Donegal, the arbutus, laurustinus, and fuschia, grow luxuriantly in the open air; and myrtles thrive so well in the open air, that they cover the walls of houses to the height of eight or ten feet. Mild westerly and south-westerly winds, tempered by the warm currents of the Atlantic, and charged with its vapours, blow for nearly three months in the year. The climate, although mild, is very variable along the south and west, and the ripening of the crops is often retarded, and the harvest obstructed, by the wet setting in early in autumn. The humidity of the climate varies much in different districts of the country; in the south and south-west forty-two inches is the average fall of rain, while in the north-east it is little more than half that amount. In the south, the harvest is a month earlier in general than in the extreme north, and a fortnight before the midland districts.

3. Mountains.—In glancing at the superficial features of the country, we have already indicated the positions of the mountainous parts of Ireland, for there are scarcely any great *mountain ranges*, properly so called. Except we consider the Wicklow range, with its lovely glens and valleys, the Mourne mountains, and the long ranges of Slievenaman, Slieve Bloom, and Knockmildown, entitled to the name of mountain ranges, the hills of Ireland occur in isolated groups.

The following are the names, situations, and heights of principal mountains of Ireland:—

	Height in Feet.
Macgillicuddy's Reeks, in County Kerry,	3,404
Slievh Donard, Mourne Mountains, in County Down,	2,809
Lugnaquilla, Wicklow Mountains, in County Wicklow,	3,039
Mangerton, Lake of Killarney, in County Kerry,	2,693
Croagh Patrick, in County Mayo,	2,650
Comeragh, in County Waterford,	2,160

4. Plains.—We have already noticed the great plain in the centre of Ireland; besides which there are several extensive plains in other parts of the island; those in the counties of Tipperary and Limerick are possessed of an extraordinary degree of richness and fertility, while the level pasture lands on the banks of the Shannon and Fergus are said to be the richest in the United Kingdom. Indeed, a great portion of the soil of Ireland, except the part covered by mountains and irreclaimable bogs, is richer, more fertile, and better adapted both for grazing and agricultural purposes, than any part of Europe. A vast extent of bog or morass occupies a great portion of the plains of Ireland, and extends along the banks of the Inny, skirts the Shannon for miles in its course through Longford, Roscommon, and King's County, and, if we include the great Bog of Allen, stretches over a large portion of Kildare, Carlow, and King's and Queen's Counties; these bogs, although wet and deep, and present a dreary appearance, are not without their value, as they supply the inhabitants with fuel; they consist of peat or turf, of various degrees of hardness, from a soft pulpy and fibrous mass, to a compact substance, capable of being cut into any form. A great extent of Irish bog is said to be susceptible of profitable cultivation.

5. Rivers.—From the peculiar arrangement of the mountains of Ireland, the course of the rivers are necessarily short. A great extent of the centre of the island is, as we have mentioned, occupied by a vast plain; and the mountains being external to this plain, little room is left between them and the sea for rivers of any lengthened course. The rivers of Ireland are divided into three groups—those that drain the central plain, those that drain the mountainous districts external to the plain, and those that fall into the great river Shannon.

The following are the names and directions of the chief rivers of Ireland, the counties they flow through, the chief towns on their banks, and the seas or rivers into which they fall:—

Name and Direction.	Counties through which they Flow.	Chief Towns on their Banks.	Termination.
Shannon, ...S.S.W. W.	Separates Roscommon, Galway, and Clare, from Leitrim, Longford, Westmeath, King's County, Tipperary, Limerick, and Kerry.	Leitrim, Carrick, Athlone, Killaloe, Limerick.	Atlantic; length 224 miles.
Blackwater, ...E.S.E.	Cork and Waterford.	Youghal, Mallow, and Fermoy.	Enters the sea at Youghal Bay.
Barrow, ...S.	Separates Queen's County and Kilkenny on the west from Kildare, Carlow, and Wexford on the east.	Carlow, New Ross, and Athy....	Waterford Harbour.
Suir, ...S.S.E.	Tipperary, and between Kilkenny and Waterford.	Waterford, Carrick, Clonmel, and Thurles	Waterford Harbour.
Nore, ...S.E.	Kilkenny.	Kilkenny	Falls into the Barrow.
Lee, ...E.	Cork.	Cork.	Cork Harbour.
Slaney, ...S.S.E.	Carlow and Wexford	Wexford, Enniscorthy, Tullow.	Wexford Harbour.
Ovoca, ...S.E.	Wicklow.	Arklow.	St. George's Channel.
Liffey, ...W.N.E. E.	Wicklow, Kildare, and Dublin County	Dublin.	Dublin Harbour, after a very winding course.
Boyne, ...N.E. E.	Kildare and Meath	Drogheda, Navan, and Trim. ...	Irish Sea.
Bann, ...N.	Down, Armagh, and between Antrim and Londonderry	Coleraine.	North Channel.
Foyle, ...N.W.N. N.E.	Tyrone and Londonderry	Londonderry, Lifford, Newton-Stewart, and Omagh	North Channel.
Lagan, ...N.N.E.	Down, and between Antrim and Down	Belfast.	Belfast Lough.
Erne, ...N.N.W.	Longford, Cavan, and Fermanagh	Ballyshannon, Enniskillen, and Belturbet.	Passes through Lough Erne, and flows into Donegal Bay.

The principal affluents of the Shannon are—the Boyle, the Inny, the Suck, the Brusna, and the Maig.

None of the rivers of Ireland are naturally of importance to internal navigation; but the Shannon has been made naviga-

ble to Lough Allen by deepening its bed and forming locks at a great expense; the Barrow has been made navigable in the same way to Athy; the Foyle, by canal, to Strabane; the Suir is naturally navigable for barges to Clonmel; and several other rivers have been artificially united by canals which intersect a considerable portion of the kingdom.

6. Lakes.—As may have been gathered from our preceding remarks on the configuration of the country, the lakes of Ireland are both extensive and numerous. Putting them all together they cover a surface of 455,400 acres.

The following are the principal lakes, their position and extent:—

(1.) *In the North of Ireland; Province of Ulster.*

Names.	Size.	Locality, &c.
Lough Neagh	20 miles long, 12 broad; covers 100,000 acres.	Surrounded by the counties of Antrim, Down, Armagh, Tyrone, and Londonderry.
Lough Erne	Consists of 2 basins, the largest 20 miles by 12.	Beautiful lake in Fermanagh, studded with numerous islands.
Lough Derg.	Small lake.	In Donegal, containing some islets.

(2.) *In the West of Ireland; Province of Connaught.*

Lough Conn.	Of considerable extent.	In Mayo, 30 feet above the level of the sea.
Lough Mask.	Of considerable extent.	On the borders of Galway and Mayo, 21 feet above the level of the sea.
Lough Corrib.	24 miles long, 4 miles broad.	In Galway; a beautiful lake studded with islands; 16 feet above sea level.

(3.) *Lakes in the course of the Shannon.*

Lough Allen.	A small lake.	In the county of Leitrim.
Lough Ree.	Of considerable extent.	Between Roscommon on the west, and Longford and Westmeath on the east.
Lough Derg.	18 miles long, 4 broad.	Separates Galway and Clare from Tipperary.

(4.) *In the South of Ireland; Province of Munster.*

Lakes of Killarney.	*Upper Lake*, 3 miles long by $\frac{3}{4}$ mile broad. *Lower Lake*, 7 miles long, 3 miles broad.	These beautiful sheets of water lie in the county of Kerry. They are enclosed on all sides by mountains 2,000 to 3,000 feet high, which are clothed with the richest natural wood of every kind.

7. Bays, Gulfs, and Straits.—Numerous bays and gulfs, which are generally denominated *loughs*, indent the island on all sides, and are of considerable importance to commerce.

(1.) *On the east coast are the following:—*

Name.	Size.	Remarks.
Belfast Lough.	13 miles long, 6 to 8 miles wide.	It affords good anchorage; but, from the shoals at its extremity, vessels can only reach Belfast with the flood tide.
Strangford Harbour.	15 miles long, 5 to 6 miles mide.	Has a narrow dangerous entrance; is a beautiful bay.
Carlingford Bay.	11 miles long, 2 miles wide.	A fine haven in Louth, with 20 fathoms water; but has a dangerous entrance, from a shallow rocky bar.
Dundalk Bay	A large basin.	In Louth, on Irish Channel. At high water it is a considerable harbour; at low water almost dry.
Dublin Bay.	A spacious bay.	Converted into a dock by long piers projecting from both sides of its fair-way, in order to remove the sandbanks.
Wexford Harbour.	Spacious island basin.	It is of irregular form, and almost land-locked, but obstructed by a shallow bar.

(2.) *On the south coast:—*

Waterford Harbour	Curves inland to a considerable distance.	Is the estuary of the Barrow, Nore, and Suir; has deep water, and admits vessels of large tonnage to Waterford, 15 miles from the sea.
Dungarvon and Youghal Harbours.	Both small.	Of minor importance.
Cork Harbour.	A capacious basin, with a deep narrow entrance.	It is one of the safest and finest harbours in Europe; could accommodate the whole navy of England.
Kinsale Harbour	Small.	Beautiful bay, and a safe and commodious retreat.

(3.) *On the south-west angle of Ireland:—*

Crookhaven and Dunmanus Bay.	Small.	Of easy access, and afford excellent anchorage.
Bantry Bay.	30 miles long, 4 to 6 miles broad.	A fine bay in the south-west of Cork. In 1796 a body of French troops landed here, but were taken prisoners.
Kenmare River	40 miles long.	An inlet of the sea, affording excellent anchorage.
Dingle Bay.	Large bay.	In Kerry. A fine bay, also affording good anchorage.

(4.) *On the west coast are:—*

Tralee Bay.	Of considerable size.	A rather dangerous basin in Kerry.
Mouth of the Shannon	70 miles long.	Between Clare on the north, and Limerick and Kerry on the south. Vessels of 300 to 400 tons can reach Limerick at its head.
Galway Bay, Clew Bay, Blacksod Bay, Broad Haven, Killala Bay, and Sligo Bay.	All large.	All lie on the coasts of Galway, Mayo, and Sligo, and are deep water inlets.
Donegal Bay	An extensive arm of the sea.	Between Donegal and Fermanagh, having several minor creeks and harbours.

(5.) *On the north coast:—*

Lough Swilly	Projects inland for 25 miles.	A long, deep, and irregular gulf in Donegal.
Loch Foyle	16 miles long by 9 broad.	A fine bay, oval, but somewhat shallow, with an entrance scarcely a mile across.

8. Capes and Promontories.—These are numerous, and generally bold and well defined, many of them being provided with lighthouses, and many also celebrated as landmarks for sailors. The more prominent are the following:—

(1.) *On the east coast.*

St. John's Point, in Down.
Dunany Point, in Louth.
Clogher Head, in Louth.
Howth Head, in Dublin.
Wicklow Head, in Wicklow.
Cahore Point, in Wexford.
Greenore Point, in Wexford.
Carnsore Point, in Wexford.

(2.) *On the south coast.*

Hook Tower, in Wexford.
Ardmore Head, in Waterford.
Kinsale Head, in Cork.
Cape Clear, in Cork.
Mizen Head, in Cork.
Crow Head, in Cork.

(3.) *On the west coast.*

Dunmore Head, in Kerry.
Loophead, in Clare, } Mouth of
Kerryhead, in Kerry, } Shannon.
Hagshead, in Clare.
Slyne Head, in Connemara.
Achil Head, in Mayo.
Urris Head, in Mayo.
Tillen Head, in Donegal.

BUILDING ARTS

Fig 1

Fig 3

Fig 2

(4.) *On the north coast.*

Bloody Foreland, in Donegal.
Malin Head, in Donegal. It is the most northerly point in Ireland.
Giant's Causeway, in Antrim; with its picturesque pavement, steps, and columns.
Bengore Head, in Antrim.
Fair Head, in Antrim, rises 630 feet above the sea, with its irregular courses and columns of tabular basalt.

9. Islands of Ireland.—These are for the most part small and of little importance. The chief are the following:—

(1.) *Off the east coast.*

Lambay, 2½ miles off the Dublin coast; celebrated for rabbits, sea-fowl, oysters, crabs, and lobsters.

(2.) *Off the south coast.*

Clear Island has a rough and uneven surface of 2,000 acres.
Tuscar Rock, 8 miles off Carnsore Point, and is a dangerous ridge rising 20 feet above the sea; is now surmounted by a lighthouse.
The Saltees, a dangerous ledge, 8 miles from land, has a floating light.

(3.) *Off the west coast.*

The Skelligs, off Kerry, a small rocky group.
Valentia, on the Kerry coast, a large fertile island of 9,600 acres.
The Blasquets, on the Kerry coast, near Dunmore Head; a favourite resort of the bird called the gourdet.
The three Isles of Arran, at the entrance of Galway Bay, containing an aggregate area of 6,823 acres.
Innisbofin, Innisturk, and Clare, considerable islands in Clew Bay.
Achil, or *"Eagle" Island*, rises to the height of 1,530 feet, and contains about 23,000 acres; off Mayo.
North and South Inniskea; small islets off Mayo.
Mullet is a curious irregular peninsula on the Mayo coast.

(4.) *Off the north coast.*

Aranmore, west of Donegal, with an area of 2,000 acres.
Tory, west of Donegal, celebrated for its fertility.
Rathlin, north of Antrim, a basaltic island, containing upwards of 3,300 acres, and yielding tolerable pasture and crops.

BUILDING ARTS.

CHAPTER VI.

In making use of the table given in last chapter, it is necessary first to find the mean width of the drain from the widths at the top and bottom. Thus, if a drain 3 feet deep were 16 inches wide at the top and 4 inches at the bottom, the mean width would be half of $16+4=10$; then, by looking in the table for the column under 10 (width), and opposite 36 (inches in depth), we find the number of cubic yards in each rod of such a drain to be 1·53, or somewhat more than one and a half. If we compare this with another drain, 20 inches wide at top, 4 inches at bottom, and 4 feet deep, we have the mean width 12, and, looking at the table under 12 and opposite 54, we find 2·75 cubic yards, or two and three-quarters to the rod. In this case, the quantity of earth to be removed is nearly twice as much as in the other, and hence, as far as regards the digging, the cost of the labour will be nearly double. But in the case of deep drains, the cost increases slightly for another reason, namely, the increased labour of lifting the earth to a surface from a greater depth.

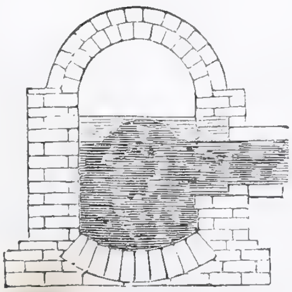
We now come to the consideration of house drainage, for the conveyance of refuse matter to the main sewer or liquid manure tank. The practice of drainage may be divided into three points of consideration, attention to all of which is absolutely necessary before efficiency can be obtained. These are—1. a proper supply of the vehicle by which the speedy conveyance of the refuse matter to its final destination is insured; 2. the proportioning of the size of drain for the current to be conveyed; 3. the shape best calculated to convey the sewage quickly, and the best methods of laying and finishing the drains.

The first point of consideration we shall now attend to, namely, the vehicle for insuring the speedy removal of the sewage. This vehicle is water. Without it no system of drains, however well devised in other points, can be efficient, as their ultimate stoppage is only a question of time, from the rapid accumulation of the solid matter in which sewage water abounds. On the importance of this vehicle in a system of drainage, a first-rate authority has the following:—"It is quite obvious, that it cannot matter in the least what pains are taken with the construction of the drain, so as to give it the form, the diameter, and so on, which scientific observation may show to be most effectual. It is plain that all this must be useless, and that all the cost of making it must be entirely wasted, if it is not amply supplied with water. No drain can be efficient through which do not flow currents of water. If, in any particular case, it be not practicable to cause a current of water to be constantly flowing through a drain, then contrivances must be adopted to cause currents to flow through it at regular and no distant intervals. Without a provision for this regular and abundant supply of water, drains not only fail in accomplishing their object, but they become positively injurious. They generate and diffuse the very poison, the formation of which it is their object to prevent." The supply of water here shown to be so important, must, as a matter of imperative necessity, be obtained from one source—the refuse water of domestic operations, and may be obtained from another source—the waste water of cisterns, or the overflow of rain water. The imperative necessity, in good drainage, of the first point, obviously does away with all house arrangements by which domestic operations, as washing, &c., are compelled to be carried on in apartments below the level of the place of final deposit of the sewage water, be this the street sewer or a liquid manure tank. On this essential point, Mr. Dempsey, in his shilling treatise on "Drainage," published by Weale of London, has the following very excellent remarks:—"Basement drainage should be abandoned, and practical methods sought of delivering the entire drainage at the level of the surface of the ground. If, indeed, no practicable methods could be devised of doing this, so as to render basement draining unnecessary, it must, of course, be admitted as part of the purpose of house drainage, in order to avoid the sacrifice of the healthiness of human beings, which we will all readily admit as the final object of the art of draining towns and buildings. The selection of the methods to be adopted for this purpose, will be dependent mainly upon the internal arrangements of the building and the occupation of its lower apartments. In the first place, *water-closets must in all cases be constructed above ground*, or, at any rate, so nearly above, that the discharge shall take place within a foot or so of the surface. However valuable the ground-floor space of any premises may be, sufficient room may, and always should, be reserved for this purpose, as this level is the most desirable for the situation of these accommodations. If placed higher, they cannot be so readily aided with the sewage water produced in the domestic offices, unless these occupy a similar elevated position; and besides this objection, is that of having an unnecessary length or extent of drains above the ground. The most desirable arrangement, therefore, is that which collects the entire drainage at or near the ground level, and there, at once and immediately, delivers it into the subterranean channels. If, however, it is in any case unavoidable that the kitchen and similar domestic offices are situated in the basement of the building, it will still be equally imperative that all the sewage water shall be delivered into the drain near the ground level. No sink or other apparatus for discharging refuse water should be retained in the basement, and the extra labour of carrying this water up to the surface level or head of the drainage, must be incurred as the penalty of this misconstruction or misappropriation of the building." This, then, is the chief source from whence the "vehicle" for insuring a speedy removal of the sewage is obtained. The secondary resource to which we have alluded is the overflow of cisterns, &c. The overflow pipe may be led at once to the head of the drain. The casual quantities, however, which will be sent down in this way, and the little force expended in a cleansing way, render it necessary to take means to store up the overflow until a sufficient quantity is obtained. This should be allowed suddenly to enter the drain, when the sweep of the rushing water will clean away the solid matter which may be lodged in the interior of the drain. This operation is termed "flushing," and should be done pretty frequently. A good method to save the overflow water of a cistern is, to partition a space

at the end, the height of which partition should be a little lower than the height of the cistern. The water will flow over this from the large to the small cistern. To flush easily, this small cistern may be provided with a valve or plug, fitting into the aperture of a pipe which leads to the head of the drain. This valve should be provided with a rod leading upwards, and connected with the end of a lever vibrating on a stud fixed to the side of the cistern; a chain being attached to the other end of the lever, and carried down to any convenient place, may be used for opening the valve when required. To take the valve into its seat, a small counterweight should be applied at the end of the lever to which the valve rod is attached. The flushing cistern may be made self-acting by using a hollow sphere, to the under side of which the valve entering the pipe leading to the drain should be attached. A rod fixed to the upper side of the sphere moving in a support, will serve to keep the sphere in its place. When the water reaches a certain height, the sphere will rise, and with it the valve, allowing the water to run to the drain. When the water in the flushing cistern falls to the level again, the sphere will descend, and the valve with it, stopping up the aperture of the drain pipe.

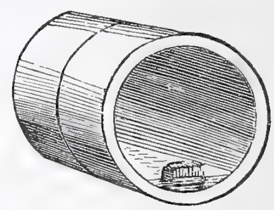
We now come to the consideration of the second point of importance, viz., the size of the drain. There have been many opinions published and advocated on this important point, and the practice of engineers, eminent in their departments, seems apparently so opposed in principle, that we think as thorough an investigation of the subject as our pages will admit of, likely to be of some value to the practical reader. There can be but one opinion as to the importance of a right understanding of the subject. Drainage is too costly a thing, and too important as regards its influence on the health, not to demand a thorough investigation of the principles on which it depends for efficient operation.

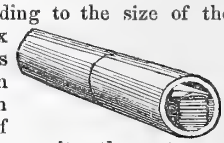
The question of the proper size of drains is confined, however, to this point:—How much smaller should drains be made than those which have been in use so long?—it appearing that nearly all who have directed their attention scientifically or philosophically to the subject, agree in holding that the large drains and sewers in use for so many years universally throughout the country—up at least to a very recent period—were out of all proportion too large for the amount of water they were intended to convey. The gentleman who seems first to have directed his attention to this subject, at least the first to make his experiments on scientific principles and publish them, was Mr. Dyce Guthrie. "This gentleman, from long-repeated and long-continued observations, was of opinion that more disease was generated by the foul emanations proceeding from inefficient house drains than from large sewers. While fully agreeing with the necessity of improvements in these latter, he held every system to be imperfect which merely hurries along the contents of the principal or main sewers, while the putrefying debris of inhabited tenements is left undisturbed in house drains." The result of his extended experience fully proved the truth of this opinion, and confirmed him in the notion that "the evils of sewers complained of, are mainly referrible to the errors existing in this department of sewage. The reason why house drains act so imperfectly, that they frequently get choked up, is simply because their too limited supply of water is spread over so great a surface, so that its power to carry along matter in suspension is lost."



The following illustration given by the Board of Health in one of their publications, gives, we believe, a very accurate idea of the ordinary condition of sewers and the house drains in connection:—"The whole evaporating surface," says the Report, "of stagnant and pestilential matter beneath the houses and streets of the metropolis, has been estimated to be equal to a canal 50 feet wide, 10 miles long, and above 6 feet deep; such as, if opened out 6 inches deep, would form a putrid swamp nearly 800 acres in extent; being nearly three times as large in surface as the whole population could lie down upon."

In illustration of the reason why a small drain, proportioned in size to the water it has to convey, is kept clean and free from deposit; while a large drain, with the same fall or inclination throughout its length, and the same quantity of water discharged through it, will accumulate deposit; we give the following illustration, derived from the Report of the Board of Health:—"In large drains, a given run of water is spread in a thin sheet, which is shallow in proportion as the bottom of the drain is wide; hence friction is increased, the rate of flow retarded, and, according to a natural law, matters at first held in suspension, and which a quicker stream would have carried forward, are deposited. If there be any elevated substance, the shallow and slow stream, having less velocity and power of floating or propelling a solid body, passes it. Thus, if, by any neglect, substances not intended to be received by a drain enter it—if, for instance, a scrubbing-brush or hearth-stone, has been allowed to go into say a 15 inch drain, the height of the water in regard to such a substance may be as in the following sketch. But if it were a 4 inch drain, the same quantity of water would assume a very different relative position, as in this smaller sketch, and it will be readily understood that the deeper stream of the contracted channel would be more powerful to remove any obstructing body. Instead of concentrating the flow of small streams, and economizing their force, the common practice is to spread them over uneven surfaces which "deadens" or "kills" them. In a small drain an obstruction raises an accumulation of water immediately, which increases according to the size of the obstruction, until four, five, or six times more hydraulic pressure is brought to bear upon its removal, than could by any possibility be the case in a large drain; for in a large drain of three or four times the same internal capacity, the water can only be drained up to the same relative height by an accumulation of matter three or four times higher, and, therefore, twenty-six or twenty-seven times greater."





CONCHOLOGY.

CHAPTER VI.

GRAND DIVISION II.—PHYTIPHAGA.

ANIMALS destitute of a projecting siphon, and generally respire by an orifice; provided with jaws, and usually feed on vegetable substances; shell with the aperture entire, being devoid of a notch or canal.

TRIBE I.—TURBINACEA.

Shell turreted or conical, with an oblong or rounded aperture, and the margin disunited.

Genus.—TURRITELLA.—*Lamarck.*

Generic Character.—Shell turreted; spire greatly elongated, consisting of many volutions; body small in proportion to the spire; aperture entire, orbicular, or subangulated; its margin disunited above, but not reflected; outer and inner lips with a slight sinus, situated generally near the upper parts, well marked in some species; a more or less distinct sinus at the inferior and inner part of the lip, which is here very slightly reflected, but not turned back; aperture furnished with a horny operculum.

Turritella proto. Plate IV. fig. 39. Found in the Tertiary deposits, and is characteristic of the Miocene strata of Lyell.

ELEMENTARY FOSSIL CONCHOLOGY.

PLATE VIII

Most of the Turritellæ are externally striate or ribbed, and the base of the volutions in some have a carinated ridge. The sinus on the outer lip is not so apparent in many specimens, as the lip is so seldom met with entire; but if the direction of the lines of growth are carefully examined, its existence will at once be recognised; the lower part of the lip is more produced in proportion as the depth of sinus increases.

This genus consists of many species, which are found in the seas of almost all quarters of the globe.

The Fossil Turritellæ are numerous, they occur in the London Clay, Greensand, and in almost all the strata of the newer formations, namely, Barton, Hordwell, Bordeaux, and Grignon.

Genus.—Cœcum.—*Fleming*

Generic Character.—Shell discoidal when young; when adult, tubular, cylindrical, arcuated, terminating anteriorly in a round aperture, with an entire margin, and posteriorly by an obtuse, rounded, or mammillated septum, indicating the point at which the original spire was cast off; operculum corneous, multispiral, with simple edges.

Cœcum trachea. Plate VI. figs. 27 and 29. From the Coral Crag, Sutton, and is found recent in the British seas.

Genus.—Tuba.—*Lea.*

Generic Character.—Shell oblong, turbinate; body and spire nearly of equal length, and acute; aperture subovate, slightly contracted both above and below.

Tuba striata. Plate IV. fig. 44. Found in the Tertiary formations of Pennsylvania, North America.

Genus.—Turbo.—*Linnœus.*

Generic Character.—Shell turbinated, spiral, solid; spire most commonly of mediocre length, sometimes very short; aperture nearly circular, but sometimes a little transverse, and slightly trapezoidal; outer lip acute, but not reflected, and subeffuse at the base; operculum solid, testaceous, covered internally with a spiral horny plate, which is extremely variable in its aspect.

Turbo tiara. Plate IV. fig. 42. *T. conicus.* Plate IV. figs. 43, 44. The former from the Mountain Limestone at Preston, and the latter from the Greensand of Blackdown.

The Turbines are liable to much variety of shape, sometimes being trochiform, at others conical, with a greatly flattened base, and a carinated margin. All those shells which are provided with a thick testaceous operculum are the only true Turbines, which renders it necessary to withdraw some of Lamarck's Trochi and Monodontæ, and to place them in the genus Turbo. The side of the thick testaceous operculum in the Turbines, on which is impressed the spiral line, is that side which is attached to the foot of the animal inhabitant, while in the thin horny opercules of the Trochi the line is external, or contrary to those of the genus Turbo.

The species of this genus are oceanic shells, inhabiting the warmer seas of the globe. They are abundant in the Mediterranean, India, and New Holland.

Fossil species are rare, and are confined to the newer formations.

Genus.—Phasianella.—*Lamarck.*

Generic Character.—Shell oblong, smooth; spire regular, somewhat acuminated; volutions rather ventricose, but the suture not well defined; aperture oblong, entire, contracted, and acutely angulated at the upper part, and rounded at its base; outer lip not continuous with the pillar lip above; inner lip white and thickened, especially at the base of the columella; operculum testaceous, thick, spiral, externally convex, with its spire on the inner side, to which the foot of the animal is adherent.

Phasianella rigidus. Plate IV. fig. 40. *P. turbinoides.* Plate IV. fig. 46. Both from the *Calcaire-grossiér* of Paris.

This genus is nearly related to *Bulimus* in form, but the latter are all land shells, whereas the Phasianellæ inhabit the ocean.

Small fossil species of Phasianellæ are found in the London Clay, and in the *Calcaire-grossier* of Paris.

Genus.—Pyramis.—*Brown.*

Generic Character.—Shell generally subulate, gradually tapering to a point; body usually short; spire long; volutions but slightly divided by the sutural line, and seldom much inflated; aperture mostly oblong-ovate, placed nearly perpendicular, with its upper angle contracted for the most part; outer lip not continuous.

Pyramis nitidus. Plate IV. fig. 48.

The shells of this genus inhabit the ocean, many of the species are found in the British seas. They are rare in a fossil state, and are met with only in the newer formations.

Genus.—Odostomia.—*Fleming.*

Generic Character.—Shell small, conical, or subulate; for the most part smooth and glossy, with an obtuse, and frequently reversed apex; surface sometimes striated, and occasionally provided with longitudinal ribs; aperture ovate, acuminated above, with a tooth-like projection or fold upon the columella.

Odostomia pellucida. Plate V. fig. 17. Found in the Coral Crag at Sutton.

The shells of this genus are marine, and the species are numerous. They differ from those of Chemnitzia, in being less turriculate, with fewer volutions, and the form of the aperture less quadrate. Twenty-four species have been detected in the British and Irish seas.

Genus.—Littorina.—*Ferussac.*

Generic Character.—Shell turbinated, generally ovate, or oblong-ovate, for the most part thick and solid; spire usually acuminated and subturreted, in some species very short, and obtuse at the apex; aperture entire, round, or slightly elliptical, sometimes a little acute above; outer lip sharp-edged, thickened within; columella somewhat flattened; operculum horny, spiral, consisting of a few rapidly enlarging volutions, and furnished with a central laterally-placed nucleus.

Littorina littorea. Plate VI. fig. 26. Found in the Crag at Aldborough.

The Littorinæ have been scattered among the genera Turbo, Phasianella, and Neritina of Lamarck. So closely are many of the Littorinæ allied in form to species of the preceding genus, that it is impossible to distinguish them without the aid of the operculum, which is horny. The operculum of the Trochi is also horny, but has more convolutions than that of Littorinæ. They inhabit the sea-shores of almost all countries. The tropical species are thinner than those of Northern latitudes.

Fossil species occur in the Tertiary formations, the Coral Rag, and inferior Oolite.

Genus.—Lacuna.—*Turton.*

Generic Character.—Shell thin; surface covered with an epidermis, conoid, or somewhat globular; aperture entire, oval, or rounded, with the lips disunited above; columella flattened, with a longitudinal groove, which terminates in an umbilicus at the superior end; provided with a horny operculum.

Lacuna reticulata. Plate V. fig. 30. Found in the Coral Crag at Sutton. The known recent species inhabit the sea, and several are found on the British coasts.

Some of the species were formerly confounded with *Natica.* They chiefly inhabit the Northern seas.

Genus.—Trochus.—*Linnœus.*

Generic Character.—Shell conical; the spire elevated, sometimes abbreviated; aperture more or less transversely and obliquely depressed, frequently quadrangular or trapeziform; its edge being oblique to the direction of the last volution, exhibiting the inferior portion of the columella; base generally flattish, discoidal, or, in some instances, concave; columella more or less arcuated, and its base truncated in some species, operculum horny, circular, and spiral, with many close-set volutions, and separated by an external spiral line; outside frequently covered with a horny epidermis.

Trochus lævigatus. Plate V. fig. 42. Found in the Crag pits at Holywell.

The operculum of this genus is invariably thin and horny, but in the species of Turbo it is thick and testaceous, while it is distinguished from that of Littorinæ by its more numerous convolutions. The general conical form and angulated aperture of the Trochi distinguish them from the Turbines, and being destitute of a notch at the base of the columella, they are known from the Monodontæ.

The Trochi are numerous, and inhabit the ocean in almost all quarters of the globe; and many of the tropical species grow to a large size.

Fossil Trochi are numerous, occurring in the newer formations, namely, the *Calcaire-grossier*, the Greensand, London Clay, the Crag, and some few as low as the Lias.

Genus.—Monodonta.—*Lamarck.*

Generic Character.—Shell turbinated; volutions convex, with a subacute spire; body large, provided with an umbilicus at its base; aperture nearly round and entire; columella with a tooth below, with a longitudinal groove, the edges of which are acute; outer lip thick, internally striated; operculum horny.

Monodonta Labadyei. Plate IV. fig. 45. Found abundantly in all the shelly beds of the great Oolite formation near Minchinhampton, and at Eparcy, France.

The shells of this genus and many of the Trochi nearly approach each other in form, but the tooth at the base of the columella at once distinguish them from that genus. Recent species are numerous, and inhabit the seas of tropical climates.

Genus.—Solarium.—*Lamarck.*

Generic Character.—Shell subdiscoidal beneath; spire obtusely conical, in some instances of a more lengthened conical form; the lower margin of the body angular, and rather sharp; umbilicus broad and deep, and reaching to the apex; its margin crenulated, and exhibiting the internal edges of the superior volutions in the form of a winding gallery: aperture wide, trapeziform, with its angles somewhat rounded, and the outer lip thin and sharp; outside covered with a horny epidermis, more or less spiral and variable in form; outer side flat; inner side furnished with an irregular, nearly lateral tubercle.

Solarium plicatum. Plate V. figs. 26, 27. Found in the London Clay at Barton Cliff.

The species of Solarium are few, and are inhabitants of tropical seas. They occur fossil in the Tertiary formations, and are also found as low as the Mountain Limestone.

Genus.—Bifrontia.—*Deshayes.*

Generic Character.—Shell discoidal, planorbicular; volutions disunited; provided with a deep umbilicus, carinated at the margin; aperture longitudinal, subtriangular, somewhat dilated; outer lip acute, separated by a deep notch at both extremities.

Bifrontia Deshayesii. Plate V. fig. 22.

This is exclusively a fossil genus, the species are few, and are chiefly met with in the Paris basin.

Genus.—Orbis.—*Lea.*

Generic Character.—Shell discoidal, planorbicular; volutions flat, rolled upon each other, and quadrate; deeply umbilicate; aperture square.

Orbis rotella. Plate V. figs. 28, 29.

This genus is known only in a fossil state, and belongs to the newer formations of North America.

TRIBE II.—SCALARIDES.

Shell destitute of plicæ or folds on the columella; margins of the aperture united in a circular form.

Genus.—Delphinula.—*Lamarck.*

Generic Character.—Shell subdiscoidal, or subconic; solid, rugose, and umbilicated; spire small, depressed; volutions few, angular, and branched; aperture entire, angular, round, and sometimes trigonal or subquadrate, with the sides united, and generally provided with a fringe, or a thick marginal ridge; operculum horny, with numerous close-set convolutions.

Delphinula calcar. Plate V. fig. 32. *D. conica.* Plate V. fig. 34. Found in the *Calcaire-grossier.* Paris basin.

There are but few species, and those inhabit tropical seas.

Fossil Delphinulæ are found in the Tertiary formations, but are very limited in number.

Genus.—Planaria.—*Brown.*

Generic Character.—Shell discoidal, depressed on both sides; volutions conspicuous, both above and below; spire very slightly produced above; concave below; aperture ovate; edges of the outer lip acute, and very slightly reflected. Destitute of an operculum.

Planaria nitens. Plate V. fig. 33.

This genus strongly resembles Planorbis, but the species are marine. We are only acquainted with two in a recent state, which were found in the Frith of Forth, near Dunbar.

One fossil species, the *nitens*, has been found in North America, by Isaac Lea, Esq. of Philadelphia.

Genus.—Scalaria.—*Lamarck.*

Generic Character.—Shell turreted, oblong or ovate; body short; spire long, composed of gibbous, distinctly defined volutions, which are in some species separated; with longitudinal, elevated, subacute, interrupted, oblique ribs, in some instances so thickened as to assume a varicose appearance; aperture almost orbicular, but mostly a slight degree longer than broad, with a thickened reflected margin; lower part of the columella formed into a subcanaliculate shape; outer lip continuous; entire operculum horny, thin and spiral.

Scalaria tenuelamella. Plate V. fig. 35. Found in the Chalk of the Paris basin.

In one or two species the ribs are indistinct, being hardly elevated above the volutions; and the reflected margin of the outer lip is most apparent in those species in which the volutions do not touch each other.

This genus contains but few species, and these inhabit the ocean. Fossil species occur in the *Calcaire-grossier* of Grignon, the newer formations of Italy, the Crag of England, and London Clay.

Genus.—Rissoa.—*Freminville.*

Generic Character.—Shell oblong or turreted, and much acuminated; body short; spire long, consisting of numerous volutions; aperture entire, oval, oblique, dilated, rather angulated above, with a slight sinus at the base of the columella; lips nearly united; outer lip slightly thickened, but its edge not reflected; operculum horny.

Rissoa acuta. Plate V. fig. 18. Found in the great Oolite at Ancliffe.

The outer lip being more thickened than the ribs, but not producing varicose sutures, together with the obscure sinus, or truncation at the base, are well-marked characters of this genus. The species are all small, inhabiting the ocean; and are pretty numerous in the Mediterranean, as well as in the British seas.

Fossil species are only found in the great Oolite, and newer strata of the Tertiary formations.

Genus.—Euomphalus.—*Sowerby.*

Generic Character.—Orbicular, conical, spire short, consisting of three or four volutions, imbricated above, smooth below; aperture of a rounded-polygonal form; umbilicus large, penetrating to the apex of the shell.

Euomphalus pentangularis. Plate V. fig. 21. Found in the Carboniferous Limestone of Ireland.

The shells of this genus are entirely fossil, the species strongly resembling those of Delphinula; the volutions of which, however, increase in size more rapidly than in Euomphalus. They are met with in the Carboniferous Limestone, the Chalk, and Chalk Marl.

Genus.—Eulima.—*Risso.*

Generic Character.—Shell elongated, pyramidal, smooth; spire long, formed of numerous angulated volutions, terminating in an acute slightly tortuous apex; aperture oval, anteriorly rounded, acute at the posterior union with the body volution; outer lip slightly thickened; columella smooth.

Eulima labiosa. Plate V. fig. 10. Found only in a fossil condition.

Genus.—Chemnitzia.—*D' Orbigny.*

Generic Character.—Shell turreted, elongated, acute, and smooth; volutions often deeply constricted, or sulcated in their middle parts; apex of the spire sinistral; sutures of the volutions well defined; aperture oval or angulated, anteriorly large, retracted posteriorly; columella straight and smooth, sometimes with a plication; outer lip thin and smooth; operculum corneous, pear-shaped, marked by lines of growth, and having the imperfect rudiments of a spiral nucleus at its extremity.

Chemnitzia Lonsdalei. Plate VI. fig. 28. From the planking beds of the great Oolite, Minchinhampton Common.

The genus Chemnitzia consists of shells inhabiting the ocean, of which eight have been found in the British and Irish seas. The shells are all minute.

Genus.—Alvania.—*Leach.*

Generic Character.—Shell elongate, subulate, and turriculate, with an elevated spire and a papilliform and reversed apex; volutions numerous, convex, covered with elevated striæ; aperture ovate; outer lip thickened, with a slightly reflected inner lip, and a small umbilicus; operculum corneous.

Alvania ascaris. Plate V. fig. 11. From the Coral Crags, Sutton. Recent species are found on the North coasts and North seas.

Genus.—Cirrus.—*Sowerby.*

Generic Character.—Shell spiral, conical, with a hollow funnel-shaped axis; volutions contiguous, numerous, rounded, or slightly angulated.

Cirrus depressus. Plate V. fig. 23. Found in the Chalk, Sussex.

This genus consists entirely of fossil species, and are all nearly allied to Trochus, but may be distinguished by their funnel-shaped umbilicus. The species are chiefly met with in the Cretaceous and Oolitic groups of rocks.

Genus.—Vermetus.—*Adanson.*

Generic Character.—Shell thin, tubulose, loosely spiral in the lower part, the three or four superior volutions regularly spiral; aperture orbicular, margins united, and provided with an operculum.

Vermetus Bognorensis. Plate V. fig. 13. Found in the Sandstone rocks of Bognor, at Highgate, and Isle of Sheppy.

The shells of this genus are marine, and adhere to extraneous bodies by the attenuated and pointed extremity of the spiral part. They are found in the warmer regions of the globe. In their external form they resemble Serpulæ.

Fossil species are met with in the Cretaceous and Oolitic groups of rocks.

TRIBE III.—PLICACEA.

Shells with the aperture somewhat contracted, and the columella plaited.

Genus.—Pyramidella.—*Lamarck.*

Generic Character.—Shell turreted, smooth, polished, destitute of epidermis; body small, spire long, consisting of numerous volutions, terminating in an acute apex; aperture small, somewhat modified by the base of the body; a little oblong, and posteriorly rounded; outer lip sharp, slightly expanded, turned upwards at the base, and united to the columella; columella tortuous, and provided with several transverse plaits.

Pyramidella terebellata. Plate V. fig. 4.

The Pyramidellæ are very limited in number, and are marine shells, chiefly inhabiting the warmer portions of the globe.

Fossil species are rare, and met with only in the Cretaceous group of rocks.

Genus.—Actæon.—*De Montfort.*

Generic Character.—Shell subcylindrical, oval or oblong; usually transversely striated, and destitute of an epidermis; spire generally very short, and somewhat obtuse, in a few species a little elongated and subacute; aperture longitudinal and elongated, occupying about two-thirds the length of the shell, contracted and acute above, widened and rounded below; outer lip plain, sharp on the edge, and a little thickened in the centre; inner lip thin, slightly reflected on the columella, which is thickened, spiral, and provided with one or two plaits near its base.

Actæon cuspidata. Plate V. fig. 15. Found in the Oolite at Ancliffe. *A. Noæ.* Plate VI. fig. 37 From the Red Crag, Walton-Naze, and Brightwell.

The Actæoninæ are distinguished from the Volvariæ, by the former being destitute of a notch at the base of the aperture; and its short spire, striated or grooved external surface, and its considerably lengthened aperture, are characters which remove it from the Pyramidellæ.

This genus is rather limited in species; they inhabit the Indian Ocean, European seas, and one is found on the British coasts.

Fossil Actæoninæ occur in the *Calcaire-grossier* at Bordeaux and Paris; and they are met with in England in the Crag, London Clay, and inferior Oolite.

Genus.—Conovulus.—*Lamarck.*

Generic Character.—Shell oval or elongate, subcylindrical, with the exterior generally smooth; body large, spire short and conoidal; aperture rather long and narrow; peritreme continuous, with two or three folds upon the columella; outer lip sometimes plain, occasionally denticulated within.

Conovulus pyramidalis. Plate VI. fig. 39. Found in the Red Crag at Sutton. The shells of this genus are terrestrial, and inhabit various localities in Europe. Several species occur in Britain.

Genus.—Monoptygma.—*Lea.*

Generic Character.—Shell elongated; spire conical, tapering to an acute apex; aperture long, narrow, terminating below in a sharp point; pillar lip with a strong oblique fold at its centre.

Monoptygma elegans. Plate V. fig. 1.

The shells of this genus are exclusively fossil, and have hitherto only been met with in the United States, North America.

DURATION OF LIFE AMONG THE UPPER CLASSES.

At a recent meeting of the Statistical Society of London, Dr. Gray read a paper on this subject, in which he made it appear that the duration of life among the upper classes varies with their rank, being lowest in the highest, and highest in the lowest rank. Beginning with the class which has the shortest average duration of life, the several classes stand in the following order:—Kings, male members of royal houses, female members of royal houses, peers, successors to title, male members of the peerage and baronetage, members of the families of the gentry, professional men (chiefly clergymen), females of the upper classes. Comparing the duration of life among the higher classes of both sexes with that of the whole of England and Wales, he finds it to fall short; consequently, if we allow for the large mass of the gross population at the bottom of the scale, that class immersed in poverty, and surrounded with all the unhealthy accompaniments of destitution, and make some allowance for the portion engaged in employments which directly shorten life, for the gin and whisky drinking class, and for that still more debased class who live by vice, there must be a large class who enjoy a better expectation of life than either extreme, and whose longevity is such

as not only to compensate the low duration of life at the top and bottom of the social scale, but to create a fund out of which the higher average duration may be supplied.

ON A PECULIAR FIBRE OF COTTON WHICH IS INCAPABLE OF BEING DYED.

BY THE LATE WALTER CRUM, ESQ., F.R.S., VICE-PRESIDENT OF THE PHILOSOPHICAL SOCIETY OF GLASGOW.*

In the month of May last, Mr. Thomson, of Primrose, near Clitheroe, received from Mr. Daniel Kœchlin, of Mülhausen, some specimens of a purple ground printed calico, each of them containing a portion of cotton, which was white, although subjected to the same treatment by which the rest of the cloth, and even the threads which crossed the white one, was uniformly dyed. The white part of the thread was usually thicker than the rest, and little more than a quarter of an inch long. The whole fabric had been thoroughly bleached before printing, so that it contained no grease or other impurity that could resist the colouring matter.

White specks like these are not unknown or undreaded among the printers of calicoes in this country. M. Kœchlin mentions that the cotton of which they are formed is known by the name of *coton mort*, and here also it is called *dead cotton*. M. Kœchlin has been the first, I believe, to suggest that it may consist of unripe cotton, and that its fibre may be solid, wanting the hollow of the more perfect fibre. He adds, that if such should prove to be the case, its behaviour with colouring matters may affect materially the question of the mechanical or chemical nature of the union of cotton with its dye. Mr. Thomson did me the honour to transmit me the specimens for examination.

The ordinary cotton fibre, it will be remembered, is described by Mr. Thomson as a tube, originally cylindrical, but which collapses in drying. It has then the appearance of two small tubes joined together, so that a transverse section of the filament resembles in some degree a figure of 8. Until full maturity the cylinder is distended with water, in which bubbles of air are often distinguishable.

On placing a few of the fibres of the *coton mort* under the microscope, I found them to consist of very thin and remarkably transparent blades, some of which are marked or spotted, while others are so clear as to be almost invisible except at the edges. These fibres are readily distinguished from those of ordinary cotton by their perfect flatness, without the vestige of a cavity, even at the sides, and by their uniform as well as great transparency. They are often broader, too, than the usual fibre, and they show numerous folds, both longitudinal and transverse; but they are never twisted into the corkscrew form of the ordinary fibre.

It occurred to me that cotton of this description might be detected among the wool as it is imported. I searched accordingly for any portions that had a different appearance from the rest; and having collected and examined them, I found one sort whose filaments had exactly the appearance under the microscope of the *coton mort* in the pattern of M. Kœchlin. It occurs in the form of a small matted tuft, of a shining silky lustre, and usually contains in its centre the fragment of a seed, or perhaps an abortive seed. It consists of short fibres, having little tenacity. Specimens of it are found in abundance among the motes, or hard portions, called droppings, rejected by the picking machine in the preparation for spinning. Small tufts of it, however, do occasionally pass the sifting process of the picking machine; and then, their fibres being too short to be teazed out in the carding engine, or drawn into threads in the subsequent operations of cotton spinning, remain as minute lumps or knots upon the threads of better wool.

Although the microscopic appearance of the fibre in question is that of a flat single blade, the cellular character of the tissue scarcely admits of such a formation. We must rather suppose that, like the healthy unripe cotton fibre, it was originally an elongated cell or tube filled with liquid; that the seed around which it began to grow had died soon after its formation, while the fibres which clothed it were yet soft and pliable; and that the flattening, and perhaps growing together of the sides of the tube, was occasioned by the pressure from the increasing crop of cotton attached to the numerous other seeds confined in the same pod.

To explain the bearing of this peculiar structure upon the question, whether cotton wool and colouring matters form together a true chemical compound, or are held together by a merely mechanical power, I must quote a passage from a memoir on this subject, which I read to the Philosophical Society six years ago, and refer to the memoir itself for additional illustrations:—

"In many of the operations of dyeing and calico-printing, the mineral basis of the colour is applied to the cotton in a state of solution in a volatile acid. This solution is allowed to dry upon the cloth, and in a short time the salt is decomposed, just as it would be, in similar circumstances, without the intervention of cotton. During the decomposition of the salt its acid escapes, and the metallic oxide adheres to the fibre so firmly, as to resist the action of water applied to it with some violence. In this way does acetate of alumina act, and, nearly in the same manner, acetate of iron. The action here can only be mechanical on the part of the cotton; and the adherence, as I shall endeavour to show, confined to the interior of the tubes of which wools consist, or of the invisible passages which lead to it. The metallic oxide permeates these tubes in a state of solution; and it is only when its salt is there decomposed, and the oxide precipitated and reduced to an insoluble powder, that it is prevented from returning through the fine filter in which it is then enclosed.

"When the piece of cotton, which, in this view, consists of bags lined inside with a metallic oxide, is subsequently dyed with madder or logwood, and becomes thereby red or black, the action is purely one of chemical attraction between the mineral in the cloth and the organic matter in the dye-vessel, which, together, form the red or black compound that results; and there is no peculiarity of a chemical nature, from the mineral constituent being previously connected with the cotton."

To produce the purple dye of M. Kœchlin's pattern, the cloth has first to be impregnated with iron. For this purpose it is made to imbibe a weak solution of proto-acetate of iron, and afterwards dried. By exposure to the air for some days the salt is decomposed. Its acetic acid evaporates, and the oxide of iron, then become peroxide, remains in the fibre. The cloth is afterwards subjected to severe washings in hot and cold water, but its iron is not removed; and the question is, How is it retained in connection with the cotton? Mechanically, as I maintain, and probably in the interior of its hollow fibre, which it entered in a state of solution, and within which it was precipitated. Others, as I have already stated, are of opinion, after Bergman, that the combination is a chemical one; and so fully is that view carried out by Professor Runge, of Oranienburg, in his ingenious and excellent work on the Chemistry of Dyeing,† that he assumes coloured cottons to be combinations of what he calls cottonic acid with the various bases, in definite and even in multiple proportions. Thus a very pale shade of buff from oxide of iron is called *percottonate of iron;* another is called *bicottonate of iron;* and still deeper shades, *cottonate* and *basic cottonate of iron.*

But the new fibre, by the same treatment, is incapable of retaining the iron mordant, and yet both fibres have the same chemical composition and the same ultimate structure. The only difference is, that one is shaped into tubes or bags capable of holding all matters which are insoluble in water, that is, all bodies which can be caught upon a filter, while the other is possessed of no such enclosure.

* Paper read before the Philosophical Society of Glasgow.

† *Farbenchemie*, 2 vols. Berlin, 1832 and 1845.

THE METAL MANUFACTURE.

CHAPTER V.

BRASS AND BRONZE WORK—BRASS-FOUNDING.

THE sugar-moulds, the clarifying vessels, the stills and other vessels employed by distillers, the coppers for brewers, the copper baths, the copper boilers, and other vessels made of this metal, are all made simply of sheet-copper, all are hammered and annealed, and all are either riveted more or less extensively, or brazed. It is unnecessary, therefore, to enter into their details, and so pass on to a consideration of the more common alloys of copper.

The manufacture in brass, in bronze, in ormolu, and in mixed metals, which have an intermediate character between the cheapness of iron and the costliness of gold or silver, is carried on very extensively at Birmingham, chiefly for ornamental purposes. Gates and railings, vases and tripods, chandeliers, lamps, and pedestals, small busts and groups—these are among the subjects to which the manufacture relates.

Some readers probably think brass to be, like copper or tin, a simple metal; but it is not so: it is a mixture of copper and zinc, pretty nearly in the proportion of two of the former to one of the latter. A gold-coloured alloy, called 'Prince Rupert's metal,' consists of about equal weights of copper and of zinc. Bronze, for various purposes of casting, consists essentially of copper and tin, to which a little zinc or lead, or both, are sometimes added; but in every case the copper amounts to eight or nine-tenths of the entire weight. For various ornamental purposes, other mixtures of these ingredients are sometimes adopted; but, as a general standard, it will suffice to say, that brass consists of copper and zinc, while bronze consists almost wholly of copper, variously but slightly modified by other metals. The mixed metal, of whatever kind it may be, is produced by melting together the component metals into an ingot or other convenient form.

The formation of manufactured articles from brass or bronze involves mechanical operations depending on the kind of article to be made—some establishments being devoted to the manufacture of commodities in which brass tubing is principally employed, such as brass bedsteads, curtain-rods, gas-fittings, telescope-tubing, and numerous other articles. Other manufacturers, on the contrary, devote their attention principally to such goods as require castings in brass or bronze.

Brass tubing is made from sheet-metal, by cutting up the sheet into oblong strips, and bending these round a central core, or mandril, whose thickness equals the intended internal diameter of the pipe. The two opposite edges of the brass are made to lap one over the other, and are in that state soldered together. When soldered, the tube is cleansed and brightened by means of dilute acid, and is then ready for 'drawing.' This drawing has for its object the imparting to the tube a cylindrical form, which it could not perfectly attain by the process just described. A mandril or rod is passed through the tube, and the latter is drawn forcibly through a circular hole somewhat smaller than the external diameter of the tube, being at the same time pressed closely in every part to the mandril; by which action both the internal and external surface become regular, cylindrical, and smooth.

When once a rod or a tube of brass is made, the forms into which it may be brought are almost endless, by the turning-lathe, the file, the drill, and other mechanical agents; the operations in this respect differing but very little from those relating to other hard metals. By far the most important manufactures in brass and bronze are, however, those which depend mainly on casting or founding.

Brass-founding, considered as a branch of engineering, is beset with a host of empirical rules and fancies, to an extent which naturally surprises the scientific practician, when he considers it with regard to the present calculating and philosophising age. Every founder thinks he possesses the only true and orthodox system of producing first-rate castings, and as a matter of course, every one differs from his neighbour in his routine of practice, without reflecting that the process admits as fully of a reduction to scientific rules as any of its sister branches of the manipulatory art. It is scarcely necessary to observe that excellence can never be attained in any art in the prosecution of which so loose a system is tolerated; *guesswork* will ever give chance results, productive only of inconveniences and objections, which a more systematic code of regulations would entirely obviate. The number of alloys of copper which come under the generic name of brass, amount to a numerous family, and are of the greatest importance, not only to the engineer, but to artists generally. They involve the use of the following different metals, all of which are required in a greater or less degree to suit the variety of operations where brass is indispensable, namely, copper, tin, lead, zinc, antimony, and in some cases, nickel. The first four of these metals are those in the greatest request for engineering purposes. The leading metal of this series, copper, was known to the ancients previous to the discovery of malleable iron, and was applied to all the purposes for which the latter metal alone is now used. Although we find brass frequently spoken of in the scriptures, as well as in many portions of profane history, yet it is a well ascertained fact that this refers to copper, the brass of the present day being a discovery of much later date.

The word *copper* is derived from the island of Cyprus, where it was first wrought by the Greeks. The best method of obtaining it pure, where extreme purity is an object of importance, is to dissolve it in nitric acid; the solution is then diluted, and a piece of iron introduced, upon which the pure metal is precipitated—any adherent particles of iron being readily removed by washing with dilute sulphuric acid. The specific gravity of this metal is 9 nearly: it melts at a temperature of 1996° Fahr.

Tin, the next metal on our list, has also been known from the remotest ages; its specific gravity is about 7·5—it melts at a temperature of 442°; like copper, it is the nucleus of an immense number of subsidiary metals, which, however, it is not our intention to enter upon. Zinc is a metal, whose extensive range of application is only now beginning to be understood. It is found in the state of oxide and sulphuret, its specific gravity is about 7·7, its fusing point is 773°, but at a temperature of 300° it becomes extremely malleable, and may be rolled into thin leaves, or drawn into fine wire. One of its most valuable modern applications, is as a protective covering for iron, being the best known substance for this purpose.

Lead was also known to the ancients; its specific gravity is 11·4—melts at a temperature of 612°. This metal is highly poisonous, and the greatest amount of caution ought to be observed in its application to domestic purposes, as when in contact with water in open vessels it quickly tarnishes, and small crystalline scales of oxide of lead are formed, a portion of which dissolves in the water, and is again precipitated in the form of a carbonate. If, however, the water contains a very slight amount of sulphuric acid, or a soluble sulphate, this corrosion is prevented.

Antimony was discovered by Basil Valentine in the 15th century; its specific gravity is 6·7, fuses at 800.° Except as a medicine, it is seldom used in any other way than as an alloy.

The order of facility of working these metals, varies considerably with the purpose to which they are applied—thus, regarding their wire-drawing ductibility, gold, as the most ductile metal, being 1; the four first metals are as follows: copper 5, zinc 6, tin 7, lead 8. Their relative values as laminable substances are considerably different; thus under the same circumstances, copper is 3, tin 4, lead 6, zinc 7.

The following tabulated statements exhibit the most approved proportions of the most useful class of alloys, as laid down by the best authorities, together with the specific purposes to which they are adapted. The first we shall treat upon are the—

Alloys of Copper and Tin.

In this Table the quantity of tin is that which is added to 1 *lb. of copper.*

1	oz.	Soft gun metal.
1	"	A slightly harder alloy fit for mathematical instruments.
1½	"	Still harder, fit for wheels.
1½ to 2	"	Brass Guns.
2to 2½	"	Hard bearings for machinery.
3	"	Musical Bells.
3½	"	Chinese Gongs, Cymbals, &c.
4	"	Small house bells for domestic purposes.
4½	"	Large do.
5	"	Largest for churches, &c.
7 to 8	"	Speculum metal.
32	"	*Temper*, a mixture sometimes used for adding to tin in the manufacture of pewter, the object being to introduce an extremely small quantity of copper.

These are the best proportions in use at the present day; for some other peculiar objects, a slightly different mixture is adopted, as a small amount of zinc or silver, and even arsenic. The best mode of mixing the component metals of this alloy appears to be to melt each separately, and then to add the tin to the copper at the lowest stirring temperature. To complete the combination, the alloy is again melted very gradually, by placing the metal in the crucible almost as soon as the fire is lighted. The hardness of this alloy, compared with the extreme softness of the metals, gives us an example of the chemical changes effected by their combination; thus, the speculum metal, as used by Lord Rosse, is totally devoid of malleability, and from its hardness cannot be acted on by the file. We now come to the consideration of another branch of the copper alloy family, of great value in the arts: this is *Copper* and *Zinc*. The following table contains the best proportions for the principal mixtures:—

Alloys of Copper and Zinc.

⅛ to ½	oz.	This addition is used principally for the purpose of producing sound copper castings.
1 to 1¼	"	Gilding metal for Jewellers.
2	"	Tombac or red brass.
3 to 4	"	Red sheet-brass, pinchbeck, and Bath metal.
6	"	Bristol brass, solders well.
8	"	The general proportion for all ordinary brass articles, does not solder so well as the last.
10⅔	"	Muntz's metal, used for ships fastenings, sheathing, &c.
16	"	Soft spelter solder.

From the volatile nature of zinc, the above proportions can seldom be strictly adhered to: but a slight variation does not much affect the filing and working of the metal. An alloy of *copper* and *lead* is often used in place of gun metal for inferior work, on account of its cheapness and facility of manipulation; it is very brittle, particularly if much lead is used.

The whole of the different metals just discussed, when mixed together, constitute GUN METAL or BRASS *par excellence*; this alloy is applied to a very great variety of purposes, and is the one most in demand for engineering works—the principal ones are compounded as below:—

ALLOYS OF COPPER, ZINC, TIN, AND LEAD.

1½ oz. tin, ½ oz. zinc, 16 oz. copper. An extremely tenacious metal, used where considerable strength is required.

1½ oz. tin 2 oz. brass, 16 oz. copper. Wheels, &c.

2 oz. tin, 1½ oz. brass. For articles requiring turning

2¼ oz. tin, 1½ oz. brass. Bearing nuts, &c.

1⅞ oz. tin, 1⅞ oz. zinc. A composition for general purposes, used by an engineer of eminence.

2½ oz. tin, ½ oz. zinc, 16 oz. copper. Bearings to resist great strains.

2½ oz. tin, 2½ oz. zinc, 16 oz. copper. An extremely hard metal, almost too hard for the file.

1 oz. tin, 2 oz. zinc, 16 oz. copper. Hard white button metal.

½ oz. tin, 1½ oz. zinc, 16 oz. copper. Common metal for buttons.

10 lbs. tin, 6 lbs. copper, 4 lbs. brass, constitute white solder.

14·75 tin, 144 copper, 12 brass. Alloy of the standard measure used by Government.

We might multiply these examples of the different mixtures, but as we have already extended this portion of our article to a considerable length, and have given what appear to be the best adapted for general purposes, we shall first introduce a table of their relative cohesive strengths, and then proceed to investigate the process of melting and preparing them for use.

Names of Metals.	Parts.		Parts.	Specific Gravity.	Force necessary to tear asunder 1 sq. in. in lbs. Avd.
Brass..........				...	45·882
Copper ...	10	—Tin	1	...	32·093
	8		1	...	36·088
	6		1	...	44·071
	4		1	...	35·739
	2		1	...	1·017
	1		1	...	0·725
Lead, Scotch	10	—Bismuth	1	10·827	2·826
	2		1	11 090	5·840
	1		1	10·931	7·319
Silver	5	—Copper	1	...	48·500
	4	—Tin ...	1	...	41·000
Tin, Banca,	10	—Antim.	1	7·359	11·181
	8		1	7·276	9·881
	6		1	7·228	12·632
	4		1	7·192	13·480
	2		1	7·105	12·029
	1		1	7·060	3 184
	10	—Bismuth	1	7·576	12·688
	4		1	7·613	16·692
	2		1	8·076	14·917
Tin, Banca,	1	—Bismuth	1	8 146	12·020
	1		2	8·580	10·013
	1		4	9·009	7·875
	1		10	9·439	3·871
	10	—Zinc. Indian ...	1	7·288	12·914
	2		1	7·000	15·025
	1		1	7·321	15·844
	1		2	7·100	16·023
	1		10	7·130	5·671
	4	—Antim.	1	...	11·323
	3		2	...	3·184
	1		1	7·000	1·450
Tin, English,	10	—Lead ...	1	...	6·904
	8		1	...	7·922
	6		1	...	7·997
	4		1	...	10·607
	2		1	...	7·470
	1		1	...	7·074
	8	Zinc, Goslar	1	...	10·607
	4		1	...	10·258
	2		1	...	10·964
	1		1	...	9·024

Where the proportions of any given alloy are stated decimally, the founder will derive great assistance, in mixing his metals, from the alloy balance of Mr Roberts, of Manchester. This is merely a steel-yard, whose beam is graduated to the extent of 100 divisions, along which its centre of support is moveable at pleasure, in order to give a greater or less leverage to either of the two scale pans, placed at its opposite ends. Thus, supposing an alloy of 80 parts copper and 20 zinc is required, it is only necessary to set the point of suspension, so that the leverage of each scale pan is as 20 to 80, and place as much metal in each as will cause an equilibrium, when it is evident that the requisite proportions will be exactly determined. When the alloy is a compound of several metals, the same operation is performed with any two: then one is removed and the remaining ones are severally balanced according to a new adjustment of the scale. Mr Holtzapffel,* to whom we are indebted for a great portion of our tables, introduced a very useful one for the conversion of the decimal proportions of

* Turning and Mechanical Manipulation, Vol. I.—second edition.

alloys into avoirdupois weight. It applies with equal facility to alloys containing two or more component parts, so as to bring them readily within the power of ordinary scales.

TABLE FOR CONVERTING DECIMAL PROPORTIONS

Into Divisions of the Pound Avoirdupois.

Decimal.	oz.	dr.	Decimal.	oz.	dr.	Decimal.	oz.	dr.	Decimal.	oz.	dr.
·39		1	12·89	2	1	25·39	4	1	37·85	6	1
·78		2	13·28	2	2	25·78	4	2	38·28	6	2
1·17		3	13·67	2	3	26·17	4	3	38·67	6	3
1·56		4	14·06	2	4	26·56	4	4	39·06	6	4
1·95		5	14·45	2	5	26·95	4	5	39·45	6	5
2·34		6	14·84	2	6	27·34	4	6	39·84	6	6
2·73		7	15·23	2	7	27·73	4	7	40·23	6	7
3·13		8	15·62	2	8	28·13	4	8	40·62	6	8
3·52		9	16·01	2	9	28·52	4	9	41·02	6	9
3·91		10	16·41	2	10	28 91	4	10	41·41	6	10
4·30		11	16·80	2	11	29·30	4	11	41·79	6	11
4·69		12	17·19	2	12	29·69	4	12	42·19	6	12
5·08		13	17·58	2	13	30·08	4	13	42·54	6	13
5·47		14	17·97	2	14	30·47	4	14	42·97	6	14
5·86		15	18·36	2	15	30·86	4	15	43·36	6	15
6·25	1	0	18·75	3	0	31·25	5	0	43·75	7	0
6·64	1	1	19·14	3	1	31·64	5	1	44·14	7	1
7·03	1	2	19·53	3	2	32·03	5	2	44·53	7	2
7·42	1	3	19·92	3	3	32·42	5	3	44·92	7	3
7·81	1	4	20 31	3	4	32 81	5	4	45·31	7	4
8·20	1	5	20·70	3	5	33·20	5	5	45·70	7	5
8·59	1	6	21·09	3	6	33·59	5	6	46·09	7	6
8·98	1	7	21·48	3	7	33·98	5	7	46·48	7	7
9·38	1	8	21·88	3	8	34·37	5	8	46·87	7	8
9·77	1	9	22·27	3	9	34·69	5	9	47·27	7	9
10·16	1	10	22·66	3	10	35·16	5	10	47·66	7	10
10·55	1	11	23·05	3	11	35·55	5	11	48·05	7	11
10·94	1	12	23·44	3	12	35·94	5	12	48·44	7	12
11·33	1	13	23·83	3	13	36 33	5	13	48·83	7	13
11·72	1	14	24·22	3	14	36·71	5	14	49·22	7	14
12·10	1	15	24·61	3	15	37·11	5	15	49·61	7	15
12·50	2	0	25·00	4	0	37·50	6	0	50·00	8	0

Application of the Table.

Tl e Chinese Packfong, similar to our German silver, according to D Fyfe's analysis, page 279, is said to consist of—

40·4 parts of	Copper	equivalent to	6 oz. 7 drams,	full.
25·4 —	Zinc		4 — 1 —	full.
31·6 —	Nickel		5 — 1 —	nearly
2·6 —	Iron		7 —	nearly
100·0 Parts.			16 oz. 0 —	Avd.

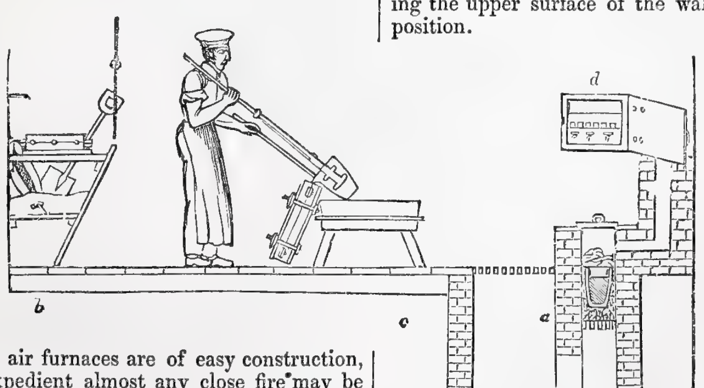
The figure annexed, represents a section of the furnace and moulding shop, as ordinarily used by the brass founder; *a*, is the furnace, *b*, the moulding trough containing the sand, *c*, is the moulding or spill trough in the centre of the shop, *d*, is the core oven, built into the wall against the flue of the furnace. The brass furnace is usually built within a cast-iron cylinder, about 20 to 24 inches diameter and 30 to 40 inches high, which is erected over an ash-pit, arrived at through a loose grating on a level with the floor of the foundry. The mouth of the furnace stands about 8 or 10 inches above the floor, and its central aperture is closed with a plate now usually of iron, although still called a *tile;* the inside of the furnace is contracted to about 10 inches diameter by fire-bricks set in Stourbridge clay, except a small aperture at the back about 4 or 5 inches square, leading into the chimney.

There are generally three or four such furnaces standing in a row, and separate flues proceed from all into the great chimney or stack, the height of which varies from about twenty to forty feet and upwards, the more lofty it is, the greater the draught; every furnace has also a damper to regulate its individual fire.

It is quite essential for constant work to have several furnaces, in order that one or two may be in use, whilst the others lie idle to allow of their being repaired, as they rapidly burn away, and when the space around the crucible exceeds about 2 or 3 inches, the fuel is consumed unnecessarily quick; the furnace is then contracted to its original size with a dressing of road drift and water applied like mortar, the fire is lighted immediately, and urged vigorously to glaze the lining *.

It is also convenient to have several furnaces for another reason, as when a single casting requires more than the usual charge of one furnace, namely, about 40 to 60 lbs. two or more fires can be used. When the quantity of brass to be melted exceeds the charge of three or four ordinary air furnaces, the common blast furnace for iron is sometimes used as a temporary expedient; the practice however is bad, as it causes great oxidation and waste.

The furnaces used by the gold and silver refiners are in many respects similar to the brass furnace *a*, but they are built as a stunted wall along one or more sides of the refinery, and entirely above the floor of the same. The several apertures for the fuel and crucible are from 9 to 16 inches square, or else cylindrical, and 12 to 20 inches deep; the front edge of the wall is horizontal, and stands about 30 inches from the ground, but from the mouth of the furnace backwards it is inclined at an angle of about 20 to 40 degrees, so that the tiles, or the iron covers of the furnaces, lie at that angle. A narrow ledge cast in the solid with the iron plates covering the upper surface of the wall, retains the tiles in their position.



The small kinds of air furnaces are of easy construction, but as a temporary expedient almost any close fire may be used, including some of the German stoves and hot-air stoves, that is for melting brass, which is more fusible than copper; although it is much more convenient that the fire be open at the top, so that the contents of the crucible may be seen without the necessity for its removal from the fire. Such stoves, however, radiate heat in a somewhat inconvenient manner, and to a much greater extent than the various portable furnaces, most of which are lined with fire-brick or clay; the lining concentrates the heat and economises the fuel.

* Road drift, or the scrapings of the ordinary turnpike roads, principally silex and alumina, is often used for the entire lining of the furnace. The refuse sand from the glass grinders, which contains flint glass, is also used for repairing them.

There are various ways of imparting to articles made of brass or of bronze an external beauty of finish, which the metal in its original state would not present. Some articles of bronze have an artificial 'verde antique' or old green tint imparted to them, by a composition applied to the surface after casting. Some have a warmer or browner tint; while some are touched on the projecting parts with a gold-coloured powder, which gives a peculiar metallic appearance; but this latter expedient is adopted chiefly where figures or ornaments of plaster are coloured to look like bronze.

Brass-work is brought to a brilliant yellow appearance by the process of lacquering, a process now conducted so skilfully that the lacquered article presents a very close resemblance to those which have been gilt. When any of the countless articles of brass which Birmingham produces has been formed by casting, drawing, stamping, chasing, or other mechanical operations, they are cleansed from grease by being heated, then laid to steep or 'pickle' in dilute acid, and brushed well with a wire or other hard brush. Each article is then dipped separately into aquafortis, by which means it speedily acquires a clear bright yellow colour, wholly free from specks and stains: indeed, it is the remarkably neat and clear-coloured appearance of the small brass goods which has given Birmingham so much celebrity for them. The cleansed and brightened article is then washed in water, dried in hot sawdust, and then burnished on some or all parts of its surface, according to the pattern and object. The burnishers are made of bloodstone, such as is used for burnishing buttons, and the mode of proceeding is exactly analogous to other metal-burnishing, the article being held in the hand, or down upon a bench, or in a lathe, according to its shape and size.

The brightened and burnished article of brass receives finally a depth and richness of tint by the process of lacquering. Lacquer is a liquid composed of spirit of wine, gum-lac, turmeric, saffron, and one or two other ingredients. The brass-work is made clean and hot, and is in that state coated with a layer of the lacquer, either by dipping or brushing. A subsequent drying finishes the process.

It will be very readily conceived that bronze statues, bells, cannon, lamps and candelabra, ornamental railings, handles, rosettes and scrolls, and the countless other articles made of brass or of bronze, however different they may be as works of high art, are all produced by modifications, more or less marked, of the processes which we have here indicated; and these few may, therefore, be taken as types of all the rest.

THE GLASS MANUFACTURE.

CHAPTER I.

HISTORY AND GENERAL OUTLINE OF THE ART OF GLASS-MAKING.

The manufacture of glass is perhaps one of the most interesting presented to the notice of readers, not only for the beauty of the material produced, but also for the remarkable modifications which the ingredients undergo in the operation, and for the manual dexterity shown in the processes. Dr. Johnson, who was not much accustomed to allude to such subjects, placed in a striking point of view the claim which glass and its manufacture have to our attention. He says:—"Who, when he first saw the sand or ashes, by a casual intenseness of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life as would, in time, constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction was mankind taught to procure a body, at once in a high degree solid and transparent; which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him at one time with the unbounded extent of material creation, and at another with the endless subordination of animal life; and, what is of yet more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though without his knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures: he was enabling the student to contemplate nature, and the beauty to behold herself."

Many opaque substances are capable of assuming a form more or less vitreous or glass-like; such as earths, some acids and salts, and metallic oxides. In porcelain we see an example of partial vitrification; for the granular texture is exceedingly fine, and a slight translucency is produced. But complete vitrification never results until after the fusion or melting of the ingredients; and we know of no means by which porcelain clay or any other earth may be melted in its simple state. But when two kinds of earth are mixed together, or, still better, when a silicious earth is mixed with certain crystalline salts, perfect fusion may be produced, and a nearer approach to transparent glass may result. Again, certain metallic oxides may be made to assume a vitreous form, and, when mixed with silex, to produce a glass possessing valuable properties. We may thence regard glass, generally speaking, as resulting from the mixture and fusion of these three kinds of ingredients; and the purpose fulfilled by each may be thus understood:—The silicious substance is the vitrifiable ingredient; the salt or alkali is the flux, by mixture with which the silex becomes fusible; and the metallic oxide, besides acting as a flux, imparts certain qualities, whereby one kind of glass is distinguishable from another.

The period when the art of making glass was first discovered is certainly not known, but as it is scarcely possible to excite a fire of sufficient heat for metallurgic operations, without vitrifying part of the bricks or stones of the furnace, (a circumstance which would very naturally suggest the idea of glass-making,) it is probable that this art is as old as that of working metals, which was anterior to any existing authentic records.

Glass-houses were at a very early period established at Tyre. Pliny states, that some merchants being driven by a storm at sea to the mouth of the river Belus, were obliged, during the time they were detained there, to dress their victuals by kindling a fire on the sand, where the herb kali grew in great abundance, and that the salts of this plant, on its being reduced to ashes, incorporated with the sand or with stones fit for vitrification, and thus produced glass. However this may have been, the sand which lay for about half a mile round the mouth of the river was peculiarly well adapted to the making of glass, while the extensive range of the Tyrian and Carthaginian commerce afforded an ample vent for the productions of the furnace.

The art of glass-making was certainly known to the Egyptians, although there exist but few specimens of antiquity to prove the fact. Most writers have erroneously referred to the beads which ornament some of the mummies as satisfactory evidence on this head; but these are not composed of glass, but of burned clay or earthenware glazed, being of a substance precisely similar to the numerous small images of mummies, beetles, and other figures. There can, however, be but little doubt that the Egyptians were well acquainted with the materials for making glass, as well as with the chemical properties of the metallic oxides for colouring it; since among the tombs at Thebes have lately been discovered small solid pieces of glass of a turquoise colour which exactly resemble, and perhaps were used for the glazing of the beads and figures of earthenware.

Fragments of white, yellow, and green glass, have likewise been found, but these may possibly have been made by the Greeks or Romans, who successively conquered Egypt, or they may have been procured from neighbouring or distant nations. Some of these fragments are flat, and of a circular form, resembling a coin nearly entire, and of an amber colour, having a well-executed figure impressed upon them in bas-relief; others are of a green hue, with Arabic characters. The former are of the size of a sixpence, the latter as large as a half-crown piece.

It appears that the glass-houses of Alexandria were celebrated among the ancients for the skill and ingenuity of their workmen, and from these the Romans, who did not acquire a knowledge of the art till a later period, procured all their glass-ware. Strabo relates, that a glass-maker of Alexandria informed him, that an earth was found in Egypt without which the valuable coloured glass could not be made; and it is stated by Pliny, that in the reign of Tiberius, a Roman artist had his house demolished for making glass malleable; and that, in consequence of this discovery, glass came into such general use as to supersede cups of gold and silver, and the glass-makers became so important, that a street was assigned them in the first region of the city.

The Chinese also are known to have possessed considerable

skill in this art; M. Abel Rimusat states, that the imitation of the precious stone Yeschm was so excellent, that it was impossible to distinguish the artificial from the real. This description of glass-ware was manufactured by the Chinese into vases of various forms, which were procured from them by the Arabians. Some were of a clear transparent white, extremely brilliant, and as pure as the precious stone: and others of a beautiful blue, they imitated equally pure. In Egypt and Syria no difference was known between the real and the artificial Yeschm: the latter being of the same form, thickness, and specific gravity as the former. It is, indeed, asserted, that in Cairo, and other parts, the artificial vases were as highly valued as those of the real Yeschm, and that enormous prices were given for them. The Chinese have also equally well imitated the Justone, which was too costly for persons of a moderate fortune. It is a coloured glass of rich appearance and greenish tint, and of such hardness and weight that it very frequently surpasses the real Ju. Small vases, figures, and almost every description of ornaments that are sculptured in the real stone, were made in this description of glass. A specimen of this imitation may be seen at the British Museum; it is of a bluish-white, resembling enamel, of an octangular figure, and about the size of a snuff-box; it is extremely hard, and, in proportion to its size, of an astonishing weight.

A most singular art of forming pictures with coloured glass seems to have been practised by the ancients, which consisted in laying together fibres of glass of various colours, fitted to each other with the utmost exactness, so that a section across the fibres represented the object to be painted, and then cementing them into a homogeneous mass. In some specimens of this art which were discovered about the middle of the last century, the painting has on both sides a granular appearance, and seems to have been formed in the manner of mosaic work; but the pieces are so accurately united, that not even with the aid of a powerful magnifying glass can the junctures be discovered. One plate, described by Winkelman, exhibits a duck of various colours, the outlines of which are sharp and well-defined, the colours pure and vivid, and a brilliant effect has been obtained by the artist having employed in some parts an opaque, and in others a transparent glass. The picture appears to be continued throughout the whole thickness of the specimen, as the reverse corresponds in the minutest points to the face, so that, were it to be cut transversely, the same picture of the duck would be found exhibited in every section. It is conjectured that this curious process was the first attempt of the ancients to preserve colours by fusing them into the internal parts of glass, which was, however, but partially done, as the surfaces have not been preserved from the action of the atmosphere.

The subterranean ruins of Herculaneum afforded many specimens of the glass-manufacture of the ancients: a great variety of phials and bottles were found, and these were chiefly of an elongate shape, composed of glass of unequal thickness, of a green colour, and much heavier than common glass; of these the four large cinerary urns in the British Museum are very fine specimens. They are of an elegant round figure with covers, and two double handles, the formation of which must convince persons capable of appreciating the difficulties which even the modern glass-maker would have in executing similar handles, that the ancients were well acquainted with the art of making round glass vessels, although their knowledge appears to have been extremely limited, as respects the manufacture of square vessels, and more particularly of oval, octagonal, or pentagonal forms. Among a great number of lachrymatories and various other vessels in the British Museum, there is a small square bottle with a handle, the rudeness of which sufficiently bears out this opinion.

The most celebrated antique vase is that which was during more than two centuries the principal ornament of the Barberini palace, and which is now known by the name of the Portland vase. It was found about the middle of the sixteenth century, enclosed in a marble sarcophagus within a sepulchral chamber under Monte del Grano, two miles and a half from Rome, supposed to be the tomb of Alexander Severus, who died in the year 235. It is ornamented with white opaque figures in bas-relief upon a dark-blue transparent ground, the subject of which has not hitherto received a satisfactory elucidation; but the design, and more particularly the execution, are truly admirable. The whole of the blue ground, or at least the part below the handles, must have been originally covered with white enamel, out of which the figures have been sculptured in the style of a cameo, with most astonishing skill and labour. This beautiful vase is sufficient to prove that the manufacture of glass was carried to a state of high perfection by the ancients.

Venice, during a long period, excelled all Europe in the fineness of its glass. Judging from the curious and interesting specimens to be seen in this country, the Venician glass-blowers must have been artists of considerable skill; and the Bohemians were also formerly very celebrated for their extensive glass-works. They invented a curious method of ornamenting glass-ware, which has since become well known, and was at one time in much repute in this country; this consisted in enclosing in the stems of wine-glasses and goblets, white and coloured opaque enamel tubes, which they twisted in white transparent glass.

Glass-making in Britain is supposed to be of very ancient date; and, if the opinion of Pennant be well founded, of a date prior to the Roman conquest. The art of manufacturing glass, as beads and amulets, was certainly long known to the Druids, as rings termed the *glain neidyr*, or Druid glass rings, are very frequently found near Aberfraw Palace. The glass amulets are about half as wide as our finger rings, but much thicker; they are usually of a green colour, but some are blue, and others curiously variegated with waves, of blue, red, and white. They are said to have been used by the Druids as a charm to impose upon the vulgar.

It is very uncertain when glass was first employed for the transmission of light and other optical purposes, or how long any of the nations of Europe have enjoyed the benefit of glass windows. One of our oldest English historians, Bede, tells us that in the year 674, the Abbot Benedict sent for artists from abroad to glaze the church and monastery of Wearmouth in the county of Durham.

Notwithstanding the interest which so important an application of glass was likely to occasion, it is probable that glazed windows were not common in these kingdoms, till several centuries after the period above-mentioned. Dr Henry says, that although the art of glass-making was introduced in the seventh century, yet it was afterwards so much neglected, that no private house had glass windows till after the conclusion of the tenth century. Before this period, the windows of houses, and even of cathedral churches, admitted the light through fine linen cloths or lattices of wood.

The first glass-houses of any importance established in England, were those at Crutched Friars, and in the Strand, London, about the middle of the 16th century. The art was afterwards encouraged by king James I. and Charles I., both of whom prohibited the importation of all foreign glass, excepting that of the most inferior kinds. The former of these monarchs, as an expedient to raise money without the aid of parliament, granted to Sir Robert Mansel an exclusive patent for making glass, which was afforded him in consideration of his having established the use of pit-coal for wood in its manufacture. He was also allowed, on the same ground, the exclusive privilege of importing drinking vessels, and every other article of glass from Italy, which could be made of a finer quality than had at that time been produced in England.

The second duke of Buckingham has the merit of improving the manufacture of British glass by bringing over several workmen from Venice: he established a considerable manufactory for making plate glass at Lambeth, about the year 1670.

During this interval, glass-making had made considerable progress in France. So early as the commencement of the 14th century, the French government had encouraged this manufacture, by ordering that gentlemen or the sons of nobility might exercise the trade without derogating from their rank; but no great advance was made until the minister Colbert, by a fortunate event, was enabled to lay the foundation of a manufactory upon the most improved principles.

Certain French artists, established at Venice, found means to obtain at Murano an exact knowledge of the processes employed in the fabrication of plate glass, and they returned to France with the hope of enriching their land with that splendid branch of art and commerce. The minister received them graciously, and having empowered them to select such a situation as they might deem best suited to their undertaking, they established themselves, in the year 1665, at Tourlaville, near Cherbourg. This company afterwards obtained a patent for making plate

glass, and an advance of 12,000 livres for four years, was granted them for this purpose, by the French government.

In the year 1688, Abram Theuart, an ingenious manufacturer, made a proposal to the court for casting glass mirrors, and engaged that they should be of a larger size than any that had been before made. This individual likewise obtained a patent, to continue for thirty years; and the first plates which he cast were made at Paris, and were of the extraordinary dimensions of 84 inches by 50 inches, a size which surprised all the artists of that day. Notwithstanding this success, not more than three years elapsed before the proprietors found it expedient to move their establishment to St. Gobin, in the department of the Aisne, and there they laid the foundation of a manufactory which soon became, and continues to remain, more extensive than any in Europe.

To return again to England, we find the art advancing with the same, and even a greater degree of rapidity. In the year 1773, a respectable body of gentlemen obtained a royal charter of incorporation, the privileges of which were confirmed to them by act of parliament, under the title of " The Governor and Company of British Cast Plate Glass Manufacturers." They subscribed a capital or joint-stock of eighty shares, of £500 each, and constructed works of considerable extent at Ravenhead, near Prescot, in Lancashire, which still rank among the most important glass-works in this country.

The art of glass-making, having been thus patronized by the nobility and gentry of the country, soon made rapid progress, and the attention of scientific men being directed to this subject, great improvements and facilities were introduced in the manufacture; and it may now be said that we equal, if not excel, those countries which were formerly our instructors, both in the beauty of the material, and in the variety and elegance of the various utensils into which it is manufactured.

Preliminary Operations.—Before proceeding to consider the manufacture of glass, it is necessary to say a few words respecting the mode of preparing the crucibles and furnaces for melting the materials. Every glass-maker is his own potter and furnace-builder. The preparation of the crucibles involves the greatest care, because upon the quality of them depends all the after processes and results. The material used is fire-clay. The clay best suited is that which contains the most silica. The crucibles, or pots, are made by forming the clay into small rolls, which are spread, layer over layer, with considerable pressure,—the whole is thus built up little by little, allowing the clay to harden, so that the shape is preserved. During the building, and afterwards, the pots are in a room, in which the temperature is regulated at about 60°, and all drafts excluded; five or six months are required in this temperature to dry them. The reason of so much care is to exclude as much air from the clay as possible; which, if it existed in quantity, would, upon the pot being brought into contact with the high temperature of the glass furnace, become so expanded as to burst; and also to insure a capacity in the pot to withstand the sudden contraction and expansion to which it is exposed. Pots are of two different constructions—closed and open; the former are used only for *flint* glass, the latter for all other descriptions in both shapes. The upper part is the most capacious; the reason for this is, that the heat reverberates from the top of the crown of the furnace directly upon the top of the pots. The pots cannot, of course, be exposed *cold* to the heat of the furnace, but have to undergo a gradual heating till they attain a white heat, and this is done in a furnace constructed for the purpose, from which all air is carefully excluded; from this furnace they are removed upon iron carriages to the glass furnace. The heat required to melt glass, especially that made without lead, is very great; yet, on account of the danger to the crucibles from any sudden rush of air, it is impossible to make use of blast, or even fanners. The proper draft is secured by the construction of an air funnel, called a cave; and by having the glass-house so constructed that it can be closed from the entrance of external air above. Upon the arch of the cave the furnace floor or seige (from the French *siege*, seat of the pots) is constructed, formed of strong heavy square bricks. The round furnace is used for flint glass, the flames finding vent by flues passing through the pillars of the furnace, having chimneys upon the outside for carrying off the smoke. Square furnaces, again, are employed for glasses without lead, a greater heat being required; which is obtained by the grate-room running the whole length of the seige. The proper construction of the furnace is of great importance to the operations of the glassmaker; in fact, good glass cannot be be made without a good furnace. There are several distinct varieties of glass manufactured; and so different are they, both in preparation and manipulation, that they may be considered separate manufactures. There are, however, only two methods by which fluid or semi-fluid glass is formed to shape, viz. casting and blowing. Casting applies, *exclusively*, to *plate* glass, and is the emptying the glass out of the pot by casting it out upon a table, the casting of glass as metal is cast being yet unpractised, —*blowing* applies to *all* other descriptions of glass.

The tools used by the glassmaker are simple. The blowing-iron —simply a hollow tube; with this the semi-liquid glass is gathered from the pot and blown out into shape; the punty, for attaching to the bottom of glass after blowing, so that the blowing-iron may be detached, and the glass, being heated up, may be cut by scissors, and afterwards formed. The shears or procelios, for shaping the glass whilst it is turned by the workmen upon the arms of his chair, or working bench. These, with the addition of a pair of scissors and pincers, are the whole of the tools.

All glass requires annealing, or cooling; the process is performed in a furnace called a lier, from the French *lier*,—figurative, perhaps, of the change in state, as well as atomic arrangement, which takes place during the cooling. We know that a change *does* take place, from the fact that glass, before cooling, is of greater bulk and less specific gravity than when cold; that it parts with a portion of *colour* during the process, probably by giving off oxygen; and that though, whilst in a fluid state, glass is a good conductor of electricity, when cold it is a non-conductor. The object of annealing is, by a gradual diminution of the temperature, to allow of that arrangement of particles necessary to the body at a low temperature, and which particular arrangement alone enables the glass to support sudden changes. The base of all glass is silica,—the most convenient form in which it is found is in fine sand; upon the due proportion of this substance in glass depends its compactness of body, brilliance and capacity to withstand sudden changes. It often happens, either on account of want of sufficient heat in the furnace, or in order to save time in the melting or founding, that too small a proportion of silica is employed. Glass, which has this fault, may be known by its rapidly attracting moisture. The different descriptions of glass made are known by the names of plate glass, German sheet or British plate, crown or window glass, bottle glass, and flint glass; there are others, but they are merely modifications of these, and need not be noticed. Plate glass is composed of sand, carbonate of soda and chalk, with small quantities of arsenic and manganese; the proportions vary at different works, but the general proportion is—Lynn sand, 400; carbonate of soda, 250; ground chalk, 35, by weight. The quality of the glass depends upon the quality of the alkali. Plate glass is melted in large open pots. The furnaces are square, containing sometimes 4, sometimes 6 pots each; when the glass is melted, which takes 22 hours, it is removed to another furnace, where the pots are smaller, of a cylindrical form. Here it is fined, which occupies 4 to 6 hours, and when free from air bubbles and impurity the pot with the glass is removed bodily from the furnace by means of a crane, and hoisted to the end of the casting-table, upon which the glass is emptied; a large iron roller which works inside the flanges of the casting-table is then made to pass over the melted glass, in order to flatten it out; it is then removed upon a wooden table on wheels to the annealing arch, which is now at high temperature, and here it is excluded from the atmosphere until cold. The glass is rough and uneven, but is afterwards cut flat by machinery, and then smoothed and polished; it is these processes which render plate glass so costly. Crown, or window glass, is of much the same composition as plate glass, except that a cheaper alkali is used; the ordinary mixture is, 500 cwt. Lynn sand, 2 of ground chalk, and 1 cwt. *each* of sulphate and carbonate of soda. The square furnace and the open pots are used, there being six pots on each furnace. It takes from 14 to 20 hours to melt this glass, and it then requires to stand from 4 to 8 hours to allow it to become free from all air bubbles, and to cool sufficiently for working. Window glass is formed by blowing: upon the blowing iron is gathered at three several times (the fluidity of glass never allowing fewer) the weight of glass necessary to produce the table, and which weighs 11 lbs.; this is then blown out, leaving a solid lump at the furthest extremity from the blowing iron, for attaching the punty; this is called the bullion. The punty being fixed to the bullion, the blowing iron is relieved by merely touching the glass with a wet iron; being firmy attached to the punty, it is removed to a small cylindrical furnace, called a flashing furnace, where a rotatory motion being given to it, increasing as the glass becomes softened by the heat, the centrifugal force, together with a little sleight of hand on the part of the workman, produces a flat circular plate or table, as it is then called.

British plate, or German sheet glass is of the same composition as plate glass, but the manipulation is different. The glass is blown into open cylinders, and, when cold, these are cut open along the length with a diamond, and placed in a flatting furnace, which is at a sufficient heat to bring the glass into a semi-fluid

state, so that it falls quite flat. The sheets thus made are afterwards cut flat and polished. The size of the sheet is restricted to what can be blown and worked by one man; it is cheaper than plate glass, because all waste is avoided, and less cutting is required. Bottle glass is composed of the cheapest materials which can be procured—ordinary pit sand, refuse alkaline waste from soap works, refuse lime from gas works, &c. The proportions of the materials vary according to quality. Bottles are blown in moulds; the glass having been blown in the mould, nothing remains but to form the mouth; this is done, the bottom being attached to an iron punty, by holding the extreme edge of the neck to the heat for a short period, and, having collected a small quantity of liquid glass upon the end of a small iron, called a ring iron, a ring of glass is allowed to cover this extreme end, and this is afterwards worked into shape by a machine which forms the inside and outside of the mouth at the same time, merely by the workman turning the bottle on the iron upon his knee once or twice. The rapidity with which bottles are made is almost incredible: a workman, with the assistance of a gatherer and blower, will begin and finish 120 dozen of quart bottles in 10 hours, which averages nearly 2¼ per minute, and this is ordinarily done; and in some works the men are restricted to 2 per minute, to prevent the work being slighted. It may not be uninteresting to observe the low price at which this description of glass can be produced, now that the duty has been removed: quart bottles can be produced at the works at about 14s. per gross; each gross weighs 2 cwt., which is equal to 7s. per cwt., or £7 per ton, for manufactured bottles; if from this we deduct for workmen and incidental expenses, £2 per ton, it would leave the price of bottle glass £5 per ton.

Flint glass is thus designated from calcined flints having been formerly used in its composition; this is now replaced by fine sand. The term flint glass is now applied to all glass into the mixture of which lead enters, and is used in the manufacture of table glass, &c. In the manufacture of flint glass the circular furnace is used, the pots surrounding the grate-room; on either side of the pots are flue-holes, which pass through the pillars, the smoke being carried up by flues outside these. The heat thus reverberates from the crown of the furnace, and is drawn round the pots previous to passing through the flue-hole. The melting pots are covered in to preserve the glass from dust, which would affect the colour. The materials used in flint glass are sand, red lead, and litharge, carbonate and nitrate of potash, arsenic, and manganese; and the greatest care is taken in the selection of them, the beauty of the glass depending mainly upon the quality of the materials. The best sand comes from Alum Bay, Isle of Wight; this is carefully washed and dried previous to using. Red lead, or litharge: this assists as a flux, and gives density, brilliancy and ductility,—the latter quality being particularly required in flint glass; it is, perhaps, owing to the superior quality of the oxides of lead prepared in England that we are in advance of other nations in the manufacture of fine flint glass. The carbonate and nitrate of potash are used wholly as fluxes; soda, though more active, is never used where quality is required, as it affects the colour. For almost every purpose, the best glass of every description is that which contains the greatest amount of silica. If the sand, lead and alkali, even though the quality were never so pure, were melted, the glass which would be produced would not be colourless, but of a pale green; and this, in all probability, is not so much the result of impurity, as the deoxidating effect of the fusion. To obviate this, it is necessary to use oxide of manganese, which, by supplying oxygen, retains the different substances in that state of oxygenation necessary to a colourless glass; if too much manganese be used the colour is slightly purple, designated by the glassmakers "high;" the green tint again, is called "low," in other words, the glass is high when it contains more than sufficient oxygen, and low when too little. Minute quantities only are necessary; from a quarter to half an ounce per cwt. is sufficient. Arsenious acid is sometimes used in flint glass, its use being to expel the carbonic acid gas present in the materials; if too much is used it gives opacity.

Glass must be considered, unfortunately for science, an imperfect body. The principal imperfection, more especially of flint glass, arises from what are called cords, or striæ, in the body of the glass, which gives it the appearance of alcohol and water imperfectly mixed; through these striæ the rays of light will not pass, but are diverged and broken. This defect is attributed to the difference in specific gravity, or want of homogeneity in the particles: this, no doubt, is true; but the question is, to what cause is this attributable? I would suggest that it may arise from the unequal distribution of heat to the materials during fusion and whilst in a fluxed state, and to the particular action consequent thereupon. The number and variety of articles manufactured in flint glass are great, and require considerable practical experience on the part of the workmen. It is impossible to describe the manner of operating, which appears even to those who have often seen it almost magical. It is certainly surprising to see an apparently opaque and fluid body in a moment become transparent and solid, and whilst undergoing this rapid change, to see it take beauty of form. The substances used for producing coloured glass are the metallic oxides, the quantity being proportioned to the depth of colour we desire to obtain. For blue glass we use oxide of cobalt; this produces a rich colour; the material, however, being expensive, it is seldom used by the glassmaker alone, but generally with an equal quantity of manganese; this materially affects the richness of the colour. Green is obtained from the oxides of copper and iron, mixed, the protoxide of copper and the peroxide of iron: equal quantities may be used, the proportions being varied according to the tint desired to be obtained: the copper produces a blue-tinted green, and the iron the yellow tint. Purple is obtained from the oxide of manganese; the purer the substance is, the finer will be the colour. The pyrolucite already referred to, especially when used in small quantities, gives a beautiful and delicate amethyst colour. Ordinary yellow is got from carburate of iron and oxide of manganese. Ruby is obtained from the oxide of gold, called the cassius precipitate: it is a colour which is neither obtained nor retained with any certainty—in fact, the modern glassmaker is quite at a loss for this colour. There can be no doubt the ancients manufactured ruby of a much finer colour than any now made, from sub-oxide of copper; this art has been lost for centuries; the difficulty is, the preventing of this substance from peroxidizing. The oxides of uranium produce beautiful tints in yellow and green. Copper scales give azure blue; oxide of chromium, emerald green. Opaque glass is produced by the addition of phosphate of lime, arsenic, and other substances. The addition of many of the metallic oxides renders glass less ductile; and in making use of these it is always well to employ an additional quantity of lead. We often hear of the superiority of the colour of ancient sheet glass to the modern, and are bound to conclude, when we see, particularly in church windows, the difference, that there is good ground for the assertion. With the exception of ruby, the modern colours are all finer than the antique. I speak of body colours—that is, glass made of coloured mixtures, called pot metal; but this is seldom used, all our modern church windows being made of white glass stained with metallic colours; this saves trouble and expense in the fitting. Glass of various colours in the same piece is obtained by casing one metal or glass with another. A small quantity of one colour having been gathered, it is blown into a small ball, and dipped into a pot of a different colour; this being rolled on an iron slab, so that an equal thickness of the second covers the first, the ball is a trifle enlarged by blowing, and may be dipped into a third and fourth colour. Care must be taken that the character of these different glasses exactly agree, that the contraction in cooling may be alike.

USEFUL PROPERTIES OF A COMPOUND OF RESIN AND LARD.

(Read before the American Association.)

A PAPER on some curious properties of a compound of resin and lard, was read by Professor Olmstead. He said:—"An accident first led me to observe something remarkable in this compound, and I have since made a few experiments, with a view of further investigating the relation between these two substances. Wishing to fit some brass of an old air-pump, so as to make a close joint with the receiver, I had been accustomed to apply to the plate a disc of leather, saturated with lard. With the hope of rendering it more completely impenetrable to air, I added to the lard a small quantity of resin, and melted them together. I expected the resin would give greater hardness to the lard, and make it fill the pores of the leather more effectually, but was surprised to find that the change produced by the resin was to impart to the lard a tendency to remain in the fluid state, so that, in a winter's day, the compound, when cold, remained in the state of a semifluid, at the temperature of a room moderately heated. I found, also, that this preparation, when applied to the leather of the air-pump, rendered it peculiarly soft, and at the same time very impermeable to air, so as to form a good joint with the receiver. But what arrested my attention more particularly was, that having inadvertently left the leather on the plate of the pump for nearly a year, during

which time the use of the apparatus was discontinued, I supposed, when I took it out again, that I should find the brass plate much corroded, as I had sometimes seen it before when exposed for a much less time to the action of the oiled disc of leather; but, on the contrary, the brass was entirely free from the corrosion, and I have uniformly found the same to be the case since, however long the leather may have remained in contact with the plate. This observation suggested another and more important use of the same preparation for lubricating the piston, which being likewise of brass, and moving in brass barrels, had before occasioned me much inconvenience, by their liability to corrode by the action of the oil used in lubricating on the brass. Moreover, the tendency of the preparation to assume the fluid state by the friction of the piston, made a very convenient and effectual application for this purpose. I have recently made a few experiments with a view of ascertaining the melting point of this compound, and the proportions of the ingredients which give the lowest melting point. The best proportions are by weight —lard, three parts; resin, one part. If the resin be added in fine powder, and the mixture well stirred (witnout the application of heat), it softens, and so nearly approaches a fluid, as to run freely when taken upon a stirring-rod at a temperature of 72 degrees. On melting the mixture, and in setting aside to cool, the following changes take place:—At 90 degrees it remains transparent and limpid; at 87 degrees a pellicle begins to form on the surface, and soon after it begins to grow slightly viscid; and as the temperature descends, it passes through different degrees of viscidity, like oils of different qualities, until at 76 degrees it becomes a dense semifluid. It is an unexpected result, that the addition of one part in four of resin, whose melting point is near 300 degrees, to lard, whose melting point is at 97 degrees, should render it more fluid, reducing its melting point to 90 degrees, imparting to it the properties of a semifluid, at a temperature as low as 76 degrees, and even rendering the preparation of a softer consistency than lard itself, at a temperature as low as 60 degrees. This compound of lard and resin has, therefore, two somewhat remarkable properties:—1. It prevents in the lard, and probably in all the animal oils and fats, that tendency to generate an acid, and thus to undergo spontaneous decomposition. A much smaller portion of resin than one-fourth gives to lard this property, destroying as it does the tendency of these substances to oxidation. Several important practical applications result from this property. Its use for lubricating surfaces of brass or copper has already been adverted to. It is equally applicable to surfaces of sheet-iron. I have found a very thin coating, applied with a brush, sufficient to preserve Russian iron stoves and grates from rusting during summer, even in damp situations. I usually add to it a portion of black-lead, and this preparation, when applied with a brush in the thinnest possible film, will be found a complete protection to sheet-iron stoves and pipes. The same property renders the compound of lard and resin a valuable ingredient in the compound of shaving soap. The quality of shaving soap is greatly improved by a larger proportion than is usually employed, so as to completely saturate the alkali; but such soap easily becomes rancid when wet with water, and suffered to remain damp, as it commonly is when in use. If a certain proportion of compound is added to Windsor soap (say one-half its weight), the tendency to grow rancid is prevented. A very soft and agreeable shaving compound, or "cream," may be made by steaming in a close cup a cake of any common shaving soap, so as to reduce it to a soft consistence, and then mixing intimately with it half its weight of our resinous preparation, adding a few drops of some odoriferous substance. The same compound forms an excellent waterproof paste for leather. Boots, when treated with it, will soon afterwards take the usual polish when blacked, and the soles may be saturated with it without danger of soiling the floor, as it does not rub off, while the leather is rendered in a high degree impervious to water. The perfect solution into which resin passes when heated with oil, suggested the possibility of improving, in this way, the quality of oils used for illumination, and by its reducing the melting point of lard, to render that more suitable for burning in solar lamps. I therefore add powdered resin to lard oil in the proportion of eight ounces of resin to one gallon of oil, and applied a moderate heat, sufficient to produce perfect solution. I then filled two solar lamps, equal in all respects, one with lard oil, the other the same holding the resin solution, and regulating the flames so as to be as nearly the same size as possible. I measured, by the method of shadows, the comparative intensities of light, which I found to be as seven to five in favour of the prepared oil. This burned with a flame of peculiar richness, plainly exceeding in density that from the simple oil; but after two hours, the flame of the prepared oil began to decline slowly, and soon became inferior to the other, an effect which doubtless arose from the clogging of the wick. I had hoped, on account of the perfect solution which the resin seemed to undergo, that the compound would burn freely without encountering this impediment; but in this respect I was disappointed, and can only say, that if some means can be devised for avoiding the tendency to clog the wick, the addition of a small portion of resin to lamp oil or lard will add essentially to its value for burning in solar lamps, by rendering it less liable to congeal, and by increasing its illuminating power.

BROWN AND BOCKLEN'S IMPROVED BOTTLE FOR EFFERVESCING DRINKS.

Many contrivances have of late been invented to secure corks in bottles without wiring or tying, and for this purpose

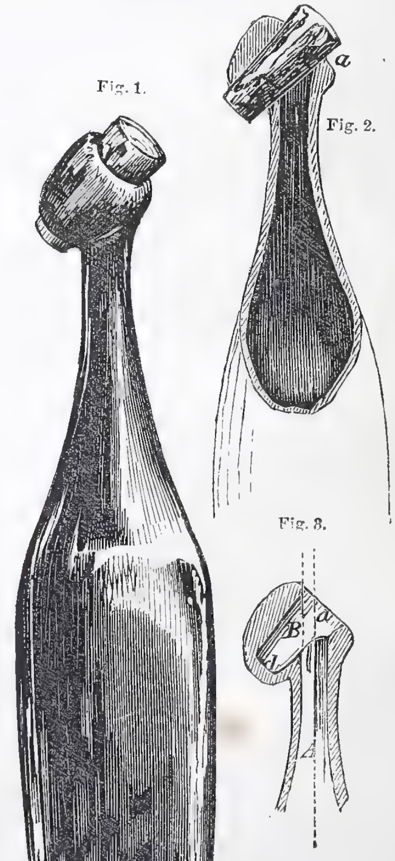


Fig. 1. Fig. 2. Fig. 3.

the necks of the bottles have been variously formed: some have been made with screws, and others have had pins inserted tranversely, and others again formed in various expen-

sive ways to receive stoppers. This invention enables the bottle to be closed by a common cork, which merely requires to be driven into its place, where the pressure of the gas acts upon it only laterally or on its side, and not on its end, and therefore does not tend in any way to expel it. The cork is inserted at the mouth of the bottle, but instead of passing down the neck, it enters an oblique passage, and passes through one side.

Fig. 1 is an outside view of one of these bottles, and fig. 2 a section of the neck, mouth, and cork passage.

A is the neck; *a* is the mouth; B is the cork passage to receive the cork. In this bottle the cork passage is open at the lower end, and both ends of the cork are exposed; but in fig. 3 a section is represented of the neck and mouth of a bottle on the same principle, with the lower end of the cork passage closed at *d*. The latter form may be used, if it be desired to compress a small quantity of air in the bottle, as is done by corking a common bottle; but the former allows no air to be compressed, which gives additional security against bursting the bottle. One of the most important characteristics of the invention is, that though the cork is exposed laterally to the pressure of the gas, an unobstructed straight passage is left through the neck of the bottle. This peculiarity will be best understood by referring to the dotted lines in fig. 3. The liquid can be poured out in as regular a stream as from a common bottle, without splashing.

The invention is well worthy of the attention of manufacturers of bottles, either in glass or stoneware.

SOME ACCOUNT OF THE EDDYSTONE LIGHTHOUSE.

THE Eddystone rocks, probably so called from the eddy or whirl formed by the waters striking against them, lie in the English Channel about 14 miles from Plymouth; even at low water the rocks are very little elevated above the sea, while at high they are completely covered—thus forming a hidden snare, the cause of much destruction of life and property. They are open in all the south-eastern points of the compass to the swell of the Atlantic and the Bay of Biscay, and from their peculiar form and position the sea breaks over them with extreme violence, even when the surrounding waters are very quiet. After a severe storm from the south-west, the sea breaks frightfully on the rocks for many days, although the storm is succeeded by days of perfect calm. It will be evident, then, that the construction of a building on such an exposed situation, sufficiently strong to resist the combined force of the winds and waves, was a matter of no ordinary difficulty.

The first was constructed by a Mr. Henry Winstanley of Essex, not a regularly bred engineer, but a person possessed with somewhat of a mechanical genius. He began his operations in 1696, and the house was finished about 1703. The first *summer* was taken up in making twelve holes in the rock, and inserting twelve iron fastenings to hold the work of the superstructure. In the second season, a central pillar of solid stonework was raised 12 feet high and 14 in diameter. This was increased during the third year to 16 feet diameter. Soon after the end of June in the same year, the workmen were enabled to lodge in the building, the work having been carried up to the vane, to a height of 80 feet. Some idea of the hardships endured may be obtained by the mention of the fact, that at this time they were detained for eleven days in the rock, the swell being so great as to preclude all possibility of landing. On the 14th November, 1698, the light first shed its cheering influence over the waters. The sea being found to break over the lantern, the central pillar was increased to 24 feet diameter, and the lantern raised 40 feet additional, which made the height to the top of the cupola of the lantern 90 feet. It appears that the joints of the stone tower were covered with hoops of metal, to prevent the sea washing out the mortar. The general appearance of the whole when finished may be gathered from the following:—Above the stone tower, which rose above the highest part of the rock 44 feet, there was placed a platform and balustrade; above this a dome, of the same diameter as the tower, was supported by eight pillars, resting upon the central tower. Above the dome, an octagonal tower, 15 feet in diameter, was made, and in this was the lantern, 10 feet diameter and 12 in height, containing the lights. A staircase made in the central tower admitted parties to the interior, the accommodations of which consisted of a store-room on the first floor, a state-room on the second, and the kitchen on the third: this last brought the height up to the level of the platform. The lodging-room was in the dome, and the octagon was occupied as a room for the attendants.

So confident was the architect of the strength and capability of this building to resist a storm, that it is said, he wished to be in the rock in the greatest storm that ever blew—his wish was too fatally gratified. On the night of the 26th November, 1703, being on the rock, the most terrible storm came on that ever blew in England; next morning not a vestige was to be seen of the structure, where it was seen but a few hours previous, towering above the waters. Such had been the fearful force of the rushing waves, that not a stone remained to show what once had been there; a small piece of iron chain alone was left, wedged firmly in a cleft of the rock, and which was cut out some fifty years afterwards. Soon after the destruction of Winstanley's lighthouse, a large vessel struck on the rock, and most of the crew perished.

Shortly after this event, an act of parliament was passed for building another, on a lease granted to Captain Lovett, or Lovell, for ninety-nine years. The person employed to construct the lighthouse was a Mr. Redyard, a draper of London. His structure was framed of wood, circular, and 90 feet in height; commenced in 1706, finished in 1709. It encountered many severe storms, but was destroyed by fire in 1755.

The principal part of Mr. Redyard's lighthouse was made of wooden beams, 71 in number, united together by bolts fastened to circular kirbs of wood, placed in the inside. On these kirbs the floors were placed. The foundation was made of stone, composed of three distinct beds of moor-stone, each bed being separated by strong timbers, united with the external upright beams. The first and second beds were composed of five courses: the third of four, the courses being 12 inches thick. The height of the solid part was 19 feet, but with the exception of the staircase well it reached 37 feet from the lowest point of the rock. The foundation or inner solid, which was surrounded on the exterior by the wooden upright beams, was secured to the rock by 36 iron cramps, some of these being arranged in a circle within one foot of the external uprights. The beams between each bed were fastened by the remainder of the cramps, arranged in a circle three feet within the outer circle. A large central mast was fastened in the solid stonework, and reached to a height above it of 48 feet. This was united to the several floorings through which it passed, thus tending materially to strengthen the whole structure. The mast was secured at the bottom by two cramps. The manner in which the iron cramps were fastened to the rock was very ingenious, and worthy of particular notice. Two holes were drilled in the rock, at a certain degree off the vertical, so that, diverging, the distance between each increased according to the depth: at 15 or 16 inches deep, they were further separate by the space of one inch than at the top. A third hole was then drilled vertically between them; and the three being cut into one, a large hole was obtained wider at bottom than top. The iron cramp was made in two pieces, the one being larger at the bottom than top; the other the reverse of this. The piece widest at the bottom was first placed in the hole, then the other piece was driven down. The annexed engraving (fig. 1) will illustrate the method. The principle is the same as the mason's "lewis" used for hoisting large stones. The two parts of the cramp being united by the bolts which attached them to the timbers, it was quite impossible to draw them out of the holes. Mr. Redyard adopted a very ingenious mode of leading the cramps: as the sea water was apt to be dashed upon the

rock, filling the cramp holes or interstices between the rock and the iron, the holes were first filled with melted tallow, then the irons were inserted hot: red-hot pewter was next poured down; being a heavier fluid it displaced the tallow, filling at the same time the most minute interstices, the tallow having prevented the salt water from entering the cavities.

Fig. 1.

The external appearance of the lighthouse, when finished, was somewhat like an "immense conical cask, but without hoops." At the base the diameter was 23, at the top of the upright beams 15 feet. The height from the highest part of the rock to the top of the upright was 62 feet. There was a balcony, surrounded by railings, in the centre of which was placed the lantern. This was octagonal, 10 feet diameter and 13 high, having windows on all sides. Mr. Redyard made his whole structure without any projecting ornament—in this respect, acting upon totally different principles from his predecessor.

The construction of the edifice was very excellent and well managed, but the nature of the materials precluded any idea of its being of a lasting description. It stood the test of some severe storms, in one of which some of the upper timbers were carried away. However, it was not fated to have a long trial, being consumed, as we have before mentioned, by fire, in the year 1755.

On the 23d of February, 1756, there arrived in London Mr. Smeaton, who has justly been termed the "father of civil engineering." He had been recommended by Lord Macclesfield, president of the Royal Society, to the proprietors of the Eddystone lease, as a person in every way qualified to plan and carry into execution the construction of the lighthouse proposed again to be erected on this dangerous rock. Some idea may be formed of the state of travelling, and of the roads in those days, when we mention, that to go from London to Portsmouth occupied Mr. Smeaton five days.

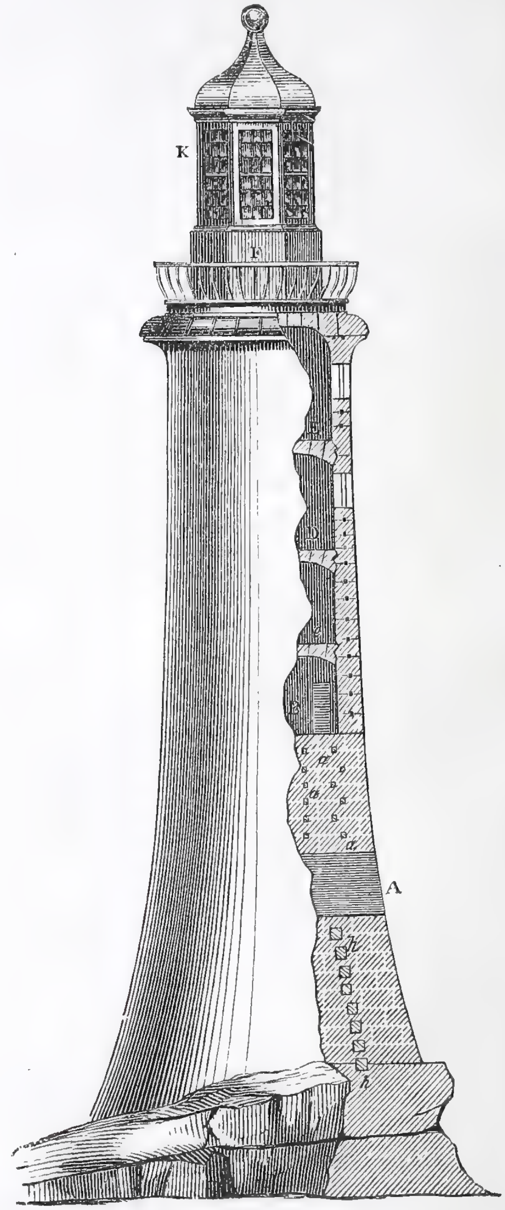
When Mr. Smeaton was engaged to draw up plans and superintend the erection of a new lighthouse on the now celebrated rocks, which had witnessed the destruction of two similar edifices, he at once gave the whole bent of his original and sound judgment to the perfecting of plans which would result in the erection of a structure calculated to resist the combined force of winds and waves. He at once determined upon a stone building; "and reasoned that, by making it very heavy, and uniting the stones firmly together, he could obtain such a weight and strength of parts, that it would be enabled to resist all external force." The following sketch (fig. 2) being a partly sectional elevation, will give an idea of the external shape, and of some of the structural details.

Instead of cramping the stones with iron, Mr. Smeaton determined to adopt the plan of dovetailing them. The annexed sketch (fig. 3) will show how this was done; it is a representation of the last course of the solid foundation. A is the entrance made in the solid stonework; B, the store-room, the floor of which is the top line of the solid stonework; C, the upper store-room; D, the kitchen; E, the bed-room; H, the balcony; F, the casement of the lantern; K, the lantern; *h h*, the joggles in the lower course; *a a*, those in the upper course.

For fourteen courses the stonework is entirely solid. At the fourteenth course this is broken, to admit of the entrance and the staircase; but with the exception of this, the solid stonework goes up as far as the floor of the first chamber, B. The different rooms are reached through apertures left in the centre of the flooring, against which are placed moveable step-ladders. The cupola is supported by eight cast-iron standards; these are secured to iron bars, resting upon the stonework. The lantern is made fast by bolts at its angles, passing through the balcony floor.

The first operation was cutting the rock into steps, upon which to lay the masonry, and thus secure a flat level foundation. There were seven courses, each of which made a level surface with the step into which it was fitted; the seventh was the first complete course. In the month of July, 1756, operations were begun; and in September the three lower steps were cut in the rock, and the upper ones in a state

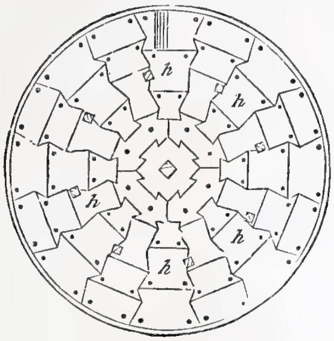
Fig. 2.



of considerable forwardness. Bad weather came on, suspending operations for the winter; the time was taken advantage of in building boats, &c., and by Mr. Smeaton, in instituting a variety of interesting experiments in cements, the value of which engineers acknowledge to this day. In May, 1757, the vessel moored near the rocks to serve as a refuge for the workmen in time of storms, was taken out and moored, and the work commenced with vigour. Dovetails were cut into each step, which held the several stones in their places, these again being so formed that they locked the others in them, thus preventing any from shifting their position. On the 12th of June, the first stone was laid in its place. In order to prevent the sea washing them away, each stone was previously prepared on shore, in such a manner that it was able to resist the action of the water even when alone in its place, and before the mortar was hardened. This was effected as follows:—One or two holes were drilled in each stone;

when laid in its place, the hole was continued in the rock or course beneath; and an oaken trenail driven down, pinning it fast into its place. The dovetails not fitting perfectly close

Fig. 3.



into each other, space being left for the mortar, notches were cut in the edges of each stone, and oak wedges driven therein, which held them fast till the mortar hardened. In order further to protect the mortar, all the joints were temporarily covered with plaster of Paris. As an instance of the amazing force of the waves in time of storm, we mention the following circumstance:—On the second course being nearly finished, a gale sprung up, the men being obliged to leave the work before setting a few stones; these they secured by lowering them into their places, and chaining them strongly to the rock; the most exposed one being further kept down by a mass of lead weighing 5 cwt. Still, in spite of all these precautions, the sea had actually lifted up this heavy weight, allowing the stone under it to be washed away along with the others. Notwithstanding all due precaution, the mortar was frequently washed out of the joints. Pozzolana cement invariably remained if it stood the first rough tide; but very difficult places were repaired by mortar mixed with oakum, chopped very small; this never failed. In August, the first six basement courses were finished, and the seventh, being the first complete one, began. The stones for this course were laid and finished in their proper places in the yard on shore. Fig. 3 represents the course of the dovetails and position of joggles, *h h*, by which the work was closely bound together.

Before being taken to pieces, each stone was numbered; this enabled them to be laid down in the proper positions without difficulty. In order that this might be done accurately, radial lines were drawn from the centre to the circumference, intersecting each stone, and concentric circles drawn through the middle of each tier. Where these lines curved the joints, a niche was sawn in the edge of the stones; this, if under water, was felt, so that the position could be at once determined, even after the course was covered with water. The several courses were retained together by joggles.

On the 25th of August, 1759, the stonework was completed, and on the 15th of the same month the light was placed in the lantern. In the construction of this noble monument of art and skill, only 421 days did the state of the sea allow the workmen to remain on the rock; and only 111 days 10 hours were really available as working hours. An idea of the difficulty and dangers which attended this undertaking may be formed from the above statement. Mr. Smeaton took his ideas of the form of the lighthouse from the trunk of an oak, which possesses all the requisites of strength combined with lightness.

The theory has in this case stood the test of practice. The Eddystone lighthouse has stood now for 96 years, and will, in all probability, remain for centuries longer.

Compared with this noble monument of man's humanity to man, the ancient Pharos—the Alexandrian light—which was deemed one of the seven wonders of the world, must sink into insignificance.

We may conceive the sublimity and terrific grandeur of the scene, as contemplated from this glorious beacon light; when the mighty waves, whose forms, perhaps engendered hundreds of miles across the Atlantic—lashed into fury, and urged along by the mighty tempest—are at last driven with gigantic force against the slender trunk of this sea-stone oak; which, built with consummate skill, may shake and shiver to its base, but still remain unharmed and unscathed—or, rolling by in majestic grandeur, the feathery foam, driven from their sprayey caps by the driving wind, to break in thunder tones, miles away upon the rocky shore. The Bell Rock Lighthouse, in the north of Scotland, built by Mr. Stevenson, may here be cited as another instance of engineering skill, triumphing over, what to other less gifted individuals might have formed insuperable difficulties. We will now give a brief description of one or two recent inventions in this department.

Captain Brown, the engineer of the Brighton Chain Pier, proposed to construct an iron lighthouse on the Wolf Rock, Land's End. It was to be ninety feet high, fourteen feet diameter at bottom, and four at the thinnest part; to be composed of circular cast-iron pieces, fitting one into another, like the joints of a telescope. The advantages to be obtained by this construction are enumerated by the inventor. The expense of iron would be less than that of stone. Being a stronger material, the surface would be less; consequently, the sea or wind would not act with such force upon it; and by having fewer joints, the capability of resisting pressure would be greater.

Mitchell's screw-pile lighthouse is the next improvement we have to notice. The inventor's attention was directed to this subject by a desire to improve the fastening of mooring chains or anchors. He conceived the idea of applying the broad threads of a screw round the periphery of a central bar, and by screwing this pile into the sandy soil in a harbour, he thought that such a hold or grasp would be taken of the soil by the blades of the screw, that the bar might form a fixed immoveable point, to which mooring buoys could be safely attached. He carried this idea into execution, and was completely successful. By a natural train of thought, he was induced to apply his invention to the sinking of piles in loose and sandy soils, for the construction of beacons, piers, &c. Such was the success of this application, that the corporation of Trinity House employed their engineer, Mr. Walker, to test the practicability of this plan on the Maplin Sands, near the mouth of the Thames. These are what are called shifting sands, and, consequently, afforded a severe test of the invention. Nine shafts of wrought-iron were screwed into the sands, eight forming an octagon; the ninth in the centre. On these were reared the superstructure, consisting of a living room for the light-keepers, a store-room for coal and water, and the lantern.

A lighthouse on this principle was built on the sands at the mouth of the river Wyre. Some idea may be formed of the rapidity with which the screw-pile structures can be raised, when we mention that this lighthouse was begun and finished in two winter months; the days being so short, the workmen were compelled to work by torch-light for a considerable portion of the time.

One great advantage of this plan is, that the under piles on which the structure is reared, present an exceeding small surface for the waves or wind to act upon.

In connection with this subject, one point will be observed, and may be commented upon with some degree of pride: it is this,—the readiness with which professional men have braved the imminent personal dangers, and encountered the privations and hardships connected inseparably with such undertakings. On perusing the narrations with which Smeaton and Stevenson have favoured us, we, at some points, read breathlessly the account of the appalling dangers which would have disheartened less energetic minds, and feel as interested therein as when we read of "hair-breadth 'scapes i'the imminent deadly breach," but with a feeling of far higher satisfaction,—the former having for their object the saving of human life, while the latter aims at the extinction of it, too often for selfish and unholy ends. The narratives of Smeaton and Stevenson "have all the charm of romance, and may well be

put side by side with any tale of the sea; they are most pleasing, however, as a record of true courage, successfully exerted in a useful undertaking." On this point an able journalist has no less truly than eloquently remarked,—"Professional gallantry in meeting danger is, we are happy to say, far from rare. The engineer is ever ready to share with the workmen in every work of risk, and there are few great works which have not some tale of gallantry to tell. The lighthouses of Eddystone, the Bell Rock, and Skerryvore, were beset with peril. In the tunnels under the Thames, Trevithick, Sir Mark Brunel, and Mr. Gravatt risked themselves; and daily, wherever a new locomotive is tried, a new boiler set up, a new mine opened, or a new engine built, some engineer puts his life at stake. Courage is not the virtue of a blue coat or of a red one: the medical man who meets typhus in the abodes of the poor, is a greater hero than he who boards another's bulwarks or who storms a breach, because he has no hope of glory or advancement, and a greater chance of danger."

The generality of people suppose that there are, in connection with engineering, no calls made upon personal courage; but it is a mistaken notion: we know of no business where cooler heads and stronger energetic minds, not easily daunted, are more required. We can scarcely conceive of a more intensely interesting book than one giving a detail of all the gallant exploits, the instances of coolness, and presence of mind in danger, exhibited by engineers, whether of masters or workmen: such would, in fact, be the *romance* of engineering.

INORGANIC CHEMISTRY.

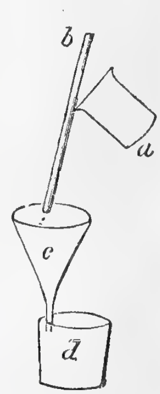
CHAPTER IX.

QUANTITATIVE ANALYSIS.

When we have ascertained what bodies are present in a compound or in a mixture, our task is in many cases but commenced. For commercial, as well as for scientific purposes, it is often needful to determine not only what elementary bodies are before us, but likewise the exact proportion in which they occur. This object may be reached by two methods: either we separate the ingredients one from another, and ascertain the weight of each—alone, or in some known combination—or we add measured quantities of some appropriate reagent, and from the amount required to produce a given effect, we calculate the amount of the substance in question. The former method is the more accurate, but requires, for the most part, a considerable time to perform. The latter —titration or volumetry—from its facility and despatch, is well suited for commercial purposes, especially where it is required to find the amount merely of one constituent in a compound or mixture. The separation needed in the former method as a preliminary to weighing, is generally effected by precipitation. The body in question is rendered soluble in water or acids, and a reagent added which shall form with some one of its constituents, a stable, determinate compound, capable of being dried and weighed. This is analysis by the *moist* or *liquid way*. Sometimes, again, the separation is effected by the aid of heat; some of the ingredients are volatilized and driven off, and their amount is determined by the loss; analysis by the *dry way*. A third general procedure, called by its originator, St. Clair Deville, the *middle way*, will be noticed in due course.

Manipulation, and General Remarks.—The quantity of material taken to operate upon may be from 20 to 25 grains, except where it is wished to determine some ingredient present only in a very minute proportion, when a larger amount may be employed. If practicable, the substance must be reduced to a very fine powder in a mortar of agate or Berlin-ware. It is next dried, in order to expel hygrometric moisture,* either by the application of a gentle heat (100° to 150° F.), or by being placed in a vacuum over sulphuric acid. The amount required is now weighed out in a small test tube, and immediately poured into the vessel where its solution is to be effected. Meantime, the empty tube, with any adhering particles, is again weighed, and the weight deducted from the gross weight as first obtained, in order thus to find the exact amount of matter employed. Solution is effected in a porcelain capsule or glass beaker, by means of water or acids. When the substance is entirely dissolved, a reagent is added which shall totally precipitate some one of the constituent elements. Thus, if we wish to find the amount of baryta in a salt of that base, sulphuric acid is added as long as anything is precipitated. The reagent is generally added in slight excess, being, towards the end of the operation, dropped in from a glass rod. It is needless to remark, that both the reagent and the solution to be analysed must be perfectly clear, and free from any sediment which would falsify the result. A precipitate condenses and subsides to the bottom of the vessel more readily, if the two liquids are warmed before being brought in contact. If this is not convenient, a gentle heat may be applied afterwards, or the liquid agitated with a glass rod, and allowed to settle. When the precipitate is sufficiently condensed, we proceed to filtration. In transferring the liquid from the beaker to the filter, the greatest care is requisite lest a portion be lost. For this purpose, it is well to employ a beaker of such size that it may not be above half-filled by the liquid, as the operation of pouring from a vessel full to the brim is exceedingly difficult. The margin of the beaker is rubbed with a little tallow, to prevent any drops from flowing down the outside, and in pouring, a glass rod, *b*, is held as in fig. 1, so as to direct the stream into the filter. The beaker and directing rod are then well washed with jets of distilled water from the washing bottle, and the rinsings added to the rest. The aperture of the funnel, *c*, should be directed against the side of the receiving vessel, *d*, to prevent any loss from splashing.

Fig. 1.



The precipitate thus collected still retains a considerable amount of foreign matter mechanically entangled in its interstices. It is therefore repeatedly washed with hot distilled water, until the liquid passes through perfectly pure. To ascertain if a precipitate is sufficiently washed, a drop is collected upon a strip of platinum foil, and evaporated by heat. If, when the water is expelled, there remains a stain of solid matter, the washing must be resumed until this is no longer the case. A few precipitates require to be washed with cold water, and some being slightly soluble, cannot be washed until the liquid passes through perfectly pure.

When washed, the filter with its contents is dried by placing the funnel in an air-bath, or drying chamber, taking care that the temperature does not rise much above 200° Fahr. When it is perfectly dry, the next step is ignition in a platinum or porcelain crucible, in order to expel the last traces of moisture, and get rid of the paper. The removal of the precipitate into the crucible without loss, requires much care and nicety. The crucible, which is first accurately weighed, is placed upon a sheet of glazed coloured paper, and the greater part of the precipitate placed in it by means of a small platinum spatula. The filter is then seized at its folded part with a pair of forceps, held exactly over the crucible, and set on fire. The precipitate and ash are allowed to fall into the crucible, and the fire is managed so, by inclining the forceps in different directions, that the part supported may burn last. It is well to tie a handkerchief over the mouth whilst performing this operation, less the ashes and fine powder be scattered by the breath. The crucible is now placed over a chemical gas lamp, and ignited; when at a full red heat, the cover may be removed in order to incinerate any parts of the filter which may have escaped combustion. When this is effected, the lid is replaced, the crucible allowed to cool, and weighed. From the total

* All powders absorb moisture from the air to a considerable extent.

weight thus obtained, that of the crucible as previously found is deducted. As a check upon the process, it is weighed again after the precipitate is removed. Should the two weighings give a different result, the operation is worthless. A further deduction is made for the weight of the ash, which is determined by burning a piece of filter-paper of equal size, and weighing the residue.

If the precipitate is volatile, or undergoes decomposition at elevated temperatures, a different process is needful. The piece of filter-paper upon which the precipitate is to be collected is carefully dried, enclosed in a platinum crucible and weighed. After the filtration and washing are over, the filter with its contents is dried in the water-bath at 212° Fahr., shut up in the same crucible and weighed. It is then taken out of the crucible, heated afresh, returned to the crucible, and again weighed. If the weight has undergone no alteration, the precipitate may be regarded as perfectly dry; otherwise the same operation is repeated until the weight becomes constant. By deducting from the gross weight that of the filter, as previously ascertained, we find the amount of the substance.

POTASSIUM AND SODIUM.

Potash and soda, if they exist as pure sulphates, carbonates, or chlorides, may be weighed as such, and the amount of the base found by calculation. If they exist in solution, they are evaporated to dryness at a gentle heat, ignited in a crucible of platinum or porcelain, and weighed. Bisulphate of potash may be neutralized by gradually adding minute fragments of carbonate of ammonia whilst it is at a red heat. Nitrates are evaporated to dryness in a capsule, and kept at 212° Fahr. (without ignition), until the weight becomes constant. Salts of the weaker acids may be first converted into sulphates, by adding sulphuric acid. If the acid, when free, is soluble in alcohol, a solution of the salt is concentrated by evaporation, mixed with chloride of platinum, and evaporated almost to dryness. The residue is treated with alcohol, when the platino-chloride of potassium remains insoluble. It is thrown upon a weighed filter, washed with alcohol, dried, and weighed on the filter.

Separation of Potash and Soda.—Both alkalies are converted into chlorides, ignited and weighed. The whole is then dissolved in water, and three times its weight of crystalline platino-chloride of sodium added. Platino-chloride of potassium is thus precipitated. From the weight of this precipitate when collected and dried, that of the chloride of potassium is calculated, and the latter again deducted from the total, shows the amount of chloride of sodium from which the soda can be deduced.

If potash and soda exist as neutral sulphates, the solution is evaporated to dryness, the residue, when thoroughly dry, accurately weighed and redissolved. The sulphuric acid present is then determined by adding a salt of baryta, as will be described below. From the weight of the mixed dry sulphates, and the quantity of sulphuric acid they produce, the respective amounts of potash and soda are calculated. 1 part neutral sulphate of potash produces 1·31818 sulphate of baryta, and 1 part neutral sulphate of soda produces 1·61111 of the same salt. The number of grains of the substance employed is multiplied by 1·31818; the product deducted from the number of grains of sulphate of baryta as found by experiment, and the remainder divided by 0·29293 (1·61111—1·31818 = 0·29293) gives the sulphate of soda required, which, deducted from the amount of substance used, leaves the sulphate of potash required. If the mixed alkalies exist as chlorides, an analogous procedure is adopted. The chlorides are weighed, and the chlorine determined with nitrate of silver. (See below.) 1 part chloride of potassium yields 1·894 chloride of silver; 1 part chloride of sodium gives 2·4 chloride of silver. Consequently, the number of grains employed is multiplied by 1·894, the product subtracted from the chloride of silver as obtained by experiment—the remainder divided by 0·506, gives the quantity of chloride of sodium required, which, subtracted from the total, gives the exact amount of the chloride of potassium.

ALKALIMETRY.

For commercial purposes it is often requisite to ascertain the actual value (neutralizing power) of a sample of potash or soda-ash. To effect this in an expeditious manner, we employ a tube called an alkalimeter, about 14 inches long, and ⁸ths of an inch in width, graduated into 100 parts, each of which contains 10 grains of water. At 23·44 parts (76·56) from the bottom is engraved *soda*, lower down at 48·96, *potash*, at 54·63, *carbonate of soda*, and at 65, *carbonate of potash*. The test acid employed is sulphuric of such a strength, that 1 degree of the alkalimeter may neutralize 1 grain pure soda. It is prepared as follows:—170·6 grains pure carbonate of soda, obtained by heating the bicarbonate to redness in a platinum crucible, are dissolved in 4 or 5 oz. of hot water. This amount contains 100 grains of pure soda. A quantity of dilute acid is prepared by mixing 1 part of oil of vitriol (by measure) with 10 of water, with which the alkalimeter is filled up to 0°, and poured gradually into the carbonate of soda until its alkaline reaction be destroyed, as ascertained by test paper, and the mixture becomes feebly acid. The amount of acid required to produce this effect is accurately observed. If it be 85 degrees, that quantity is equivalent to 100 grains of soda; but an acid is wanted, such that 100 degrees, instead of 85, may be equivalent to 100 grains soda, and this we procure by adding to 85 degrees of the acid, 15 of water. 22 degrees of this acid should neutralize 100 grains crystallized carbonate of soda, and 58½ degrees, 100 grains dry carbonate of soda.

In order to perform an analysis, *e. g.* of carbonate of soda, we weigh out 100 grains of the sample in question, and with the aid of a gentle heat, dissolve it in 4 oz. of water in an evaporating basin. Standard acid is now poured into the alkalimeter until it reaches the line marked *carbonate of soda*, and the tube filled up to 0° with distilled water. A few small bits of turmeric and litmus paper are then put into the alkaline solution, which is kept gently warm during the operation. A glass stirring-rod should also be at hand. The tube is then taken in the left hand, and its mouth being closed with the thumb, it is repeatedly inverted in order to mix the acid and water thoroughly with each other. When this is accomplished the opening is turned downwards, and the thumb slackened, so that the acid may gradually flow into the alkaline solution. The right hand is meantime employed in stirring the solution with the glass rod. When the litmus papers begin to assume a reddish tinge, the further addition of acid must be conducted with extreme caution, and the sides of the basin washed by agitating the liquid, in order to dissolve any splashings which have dried during the process, and escaped the action of the acid. When nearly neutralized, one of the litmus papers is occasionally brought out of the liquid, and upon the side of the basin; if its redness disappear,* more acid must be added until a permanent, though feeble red stain is produced. When this is observed, the alkalimeter is turned upwards, and any acid adhering to the thumb allowed to fall back into the instrument. By observing then the degree at which the liquid stands, we find the per centage of actual carbonate of soda contained in the sample.

By this process the joint amount of caustic and carbonated alkali is determined. If sulphurets, sulphites, or hyposulphites are present, they may occasion an error by taking up a part of the test acid. To avoid this fallacy, the solution of ash is mixed with chlorate of potash, evaporated to dryness, and ignited when sulphurets, sulphites, and hyposulphites are converted into sulphates, and, consequently, do not interfere. When it is required to analyse a mixture of caustic and carbonated alkali (as in ascertaining the value of a lye), the entire proportion of alkali is first ascertained as above. The amount of caustic alkali is then determined by adding solution of chloride of barium in excess to a fresh portion, and afterwards hot water. The liquid is then filtered, the carbonate of baryta washed upon the filter, and the filtered

* The fugitive stain, which inclines more to purple, is produced by the liberated carbonic acid. A permanent red is caused by the fixed acids.

liquid again submitted to an alkalimetrical process, which gives the amount of caustic alkali in grains.

Ammonia, if free, is treated with hydrochloric acid in feeble excess, and the solution evaporated to dryness in a platinum capsule in the water-bath. The residue is weighed, heated again, and once more weighed, repeating this operation until the weight becomes constant. From the weight of hydrochlorate of ammonia thus obtained, that of pure ammonia is readily calculated. With ammoniacal salts, except the hydrochlorate, we proceed as follows:—A known weight of the salt is introduced into a small retort, having a tube-funnel passing through a perforated cork in the tubulure. The extremity of the funnel should reach nearly to the bottom of the retort, and be drawn out to a point so fine, that a liquid can scarcely force its way through. The substance being introduced, the retort is connected with a receiver containing hydrochloric acid, the beak of the retort just touching the surface of the liquid. A strong solution of potash is then introduced into the retort through the funnel, and, by the application of heat, the ammonia set free by the action of the potash is distilled into the receiver. If required, more solution of potash is added, and afterwards water, to drive over all the ammonia into the dilute acid. The solution of hydrochlorate of ammonia thus obtained is treated as above.

Lithium compounds are estimated in a manner similar to that employed for potash and soda. If it exists as sulphate, a red heat will suffice to dissipate any excess of acid. If the amount of lithia is small, and potash and soda be also present, Berzelius adds a little phosphoric acid and an excess of carbonate of soda, and evaporates to dryness. On dissolving the residue in cold water, a white powder remains, the double phosphate of lithia and soda. It is washed with a little cold water, dried, ignited, and the quantity of lithia calculated from its weight. If any other bases beside the alkalies are present, this process is not applicable. If potash, soda, and lithia exist together in a solution, the mixed salts are first estimated as chlorides. The potash is next thrown down by the chloride of platinum, and its quantity determined. Any excess of platinum may be now removed by a current of sulphuretted hydrogen, and the lithia precipitated as above mentioned in the state of double phosphate. The weight of lithia thus obtained, deducted from the gross weight of the mixed salts, gives the amount of soda.

Baryta is determined by adding dilute sulphuric acid to the solution as long as a precipitate is given. The liquid is warmed, allowed to settle, and as much as possible of the clear liquid decanted off; hot water is then added, and the mixture allowed to subside. This operation is two or three times repeated before filtration, which should be performed with the best Swedish paper. Graeger recommends, after the supernatant liquid has been twice decanted off as above, to pour strong alcohol upon the precipitate, and throw it upon a filter previously moistened with weak alcohol. If these precautions are omitted, a part of the precipitate passes through the paper as a milky turbidity. This evil is less likely to happen if the original solution has been acid, very concentrated, or very dilute. It is most to be apprehended in presence of soda. The precipitate when washed and dried is ignited, air being excluded, lest the filter paper might convert a trace of the substance into sulphide of barium. If necessary, baryta may likewise be determined as carbonate, by adding carbonate of ammonia mixed with a little pure ammonia. The precipitate is washed with a little water, dried, ignited, and weighed.

To separate baryta from the alkalies, the compound is dissolved in water, or dilute hydrochloric acid, the baryta thrown down with sulphuric acid, and the alkaline sulphates determined as above. In evaporating the filtered solution down, care must be taken to avoid loss by spirting or projection.

Strontia may be estimated either as sulphate or carbonate, like baryta. The process is, however, less accurate, as the salts of strontia are less insoluble than the carbonate and sulphate of baryta. If the original salt is soluble in alcohol, the sulphuric acid may be added in a concentrated state to the alcoholic solution, and the precipitate washed with dilute alcohol. If strontia exists alone, it may be estimated like the alkalies. Ammonia may be expelled by ignition.

To separate strontia from baryta, the mixed earths are dissolved in an excess of hydrochloric acid, and hydrofluo-silicic acid added in excess. The whole is left to stand for some hours, during which the baryta is precipitated, whilst the strontia remains in solution. The precipitate is washed on a weighed filter, dried, and the baryta determined from its weight. The clear liquor is treated with sulphuric acid in excess, cautiously evaporated to dryness, and weighed as sulphate of strontia. To separate strontia from the alkalies, it may be precipitated either by sulphuric acid, or by carbonate of ammonia.

CALCIUM—LIME.

Salts of lime, if soluble in alcohol, may be determined by sulphuric acid, as those of strontia. If insoluble in alcohol, the neutral or acid solution is slightly saturated with ammonia, which should produce no precipitate. Oxalate of ammonia is then added as long as a precipitate is produced. The precipitate should be allowed to stand 12 hours in a warm place before filtration. It is then washed, dried, and strongly ignited, so as to convert the oxalate into carbonate. Lest any carbonic acid be expelled by the heat, the crucible after ignition is weighed, its contents moistened with concentrated carbonate of ammonia, dried, and heated again. If the second weighing agree with the first, no carbonic acid had been expelled.

This method is inapplicable if the lime exist in compounds soluble in an acid, though not in water, as the phosphate. In this case, sulphuric acid is added, and alcohol poured in to twice the bulk of the liquid. In precipitating lime by oxalate of ammonia, the presence of other bases should, if possible, be avoided, since the oxalate of lime is partially decomposed by all the soluble salts of metals capable of yielding insoluble oxalates and soluble salts of lime. This takes place the more readily, the higher the equivalent of the metal which has to replace the lime.

To separate lime from strontia, the two earths are precipitated from a dilute solution by carbonate of ammonia, to which a little caustic ammonia has been added. The precipitate is well washed, a little water poured upon it, and nitric acid sufficient to dissolve it is very gradually added, warming the liquid before adding more acid. The solution, when perfectly neutral, is evaporated to dryness in a bottle provided with a good stopper, which is closed as soon as all water has escaped. When the mass is cool, twice the bulk of absolute alcohol is added, and the bottle re-stoppered and shaken, without applying heat. The nitrate of lime dissolves, whilst that of strontia remains untouched. The whole is then thrown upon a balanced filter, and washed with twice its bulk of absolute alcohol, covering the funnel with a ground glass plate, lest moisture be absorbed. The filter is then weighed, and the strontia calculated from its weight. The filtrate is treated with sulphuric acid, and the precipitated sulphate of lime washed with dilute alcohol.

To separate lime from baryta, dilute the solution with a large excess of water, and add sulphuric acid as long as a precipitate appears. If the liquid is sufficiently dilute, sulphate of lime remains in solution. The liquor is warmed and filtered with the usual precautions. The precipitate is well washed with water, in order to remove any trace of sulphate of lime which may be thrown down. The filtrate is saturated with ammonia, and the lime thrown down with oxalate of ammonia as above. The original liquid must never contain free ammonia.

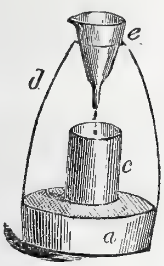
If lime, strontia, and baryta occur together, the process is as follows:—The baryta is precipitated by means of hydrofluo-silicic acid; sulphuric acid is added to the filtrate, which is then evaporated to dryness and ignited, yielding sulphates of lime and strontia. The two are mixed with thrice their weight of carbonate of soda in a platinum crucible, and the whole fused. Water is poured upon the fused mass, when the strontia and lime are obtained as carbonates which may

be separated as above. To separate lime from the fixed alkalies, it is precipitated with oxalate of ammonia, the filtrate is evaporated to dryness, ignited in a platinum crucible, and weighed. The alkali is obtained in combination with the acid present. If sulphuric acid is present, great care is needed to prevent loss by projection.

MAGNESIUM.

If magnesia occurs unmingled with any other fixed base, it is evaporated to dryness, and ignited in a weighed platinum crucible, to expel any ammoniacal salts. Dilute sulphuric acid is then poured upon the mass, the whole evaporated to dryness, and the residue slightly ignited to expel free acid. The residue is weighed, and the magnesia calculated from the result. If other fixed bases are present, and the magnesia alone has to be determined, it may be thrown down as a carbonate by carbonate of potash, an excess of which must be boiled with the magnesia solution for a long time in a platinum capsule. The whole is then filtered, and the precipitate washed with hot water, for which purpose the following apparatus will be found convenient (fig. 2): *a* is a tin or copper vessel containing water; *b*, a wire-grating upon which rests *d*, a beaker deprived of its bottom. The funnel, *e*, is supported by a ring, *f*, resting upon *d*, and a beaker, *c*, is placed below to receive the filtrate. The whole is then set over a lamp, or on the hot plate of a furnace, when the atmosphere of steam in *d* prevents the filter from cooling. When the liquid running through the filter leaves only a slight stain upon platinum foil, the precipitate is dried, thoroughly ignited, and weighed. After this, the magnesia may be treated with water. If carbonate of potash is still present, the whole is washed with hot water, again ignited and weighed. It is then, if potash was present, redissolved in dilute hydrochloric acid. A trace of silica generally remains, which is collected on a filter, washed, dried, ignited, weighed, and its weight deducted from that of the magnesia. If ammoniacal salts were present, they must be decomposed before the whole of the magnesia can be precipitated, which is effected by prolonged boiling with an excess of carbonate of potash.

Fig. 2.



Separation of Magnesia from Lime.—The compound is dissolved in nitric acid, the solution neutralized with ammonia, and the lime precipitated as an oxalate. After the solution has been digested for some time and allowed to settle, it is filtered, the precipitate washed, dried, ignited, as above. The filtrate containing magnesia may now be treated according to the former process. Or the compound is dissolved in muriatic acid, and first sulphuric acid and then alcohol added; the latter to about twice the bulk of the solution. The sulphate of lime produced is washed with dilute alcohol; the filtrate is gently heated for a long time to expel the alcohol, and the magnesia is then precipitated. If phosphoric acid be present, the magnesia is precipitated by a solution of phosphate of soda mingled with ammonia, leaving the whole, after precipitation, to digest in a warm place for twelve hours.

The separation of magnesia from strontia and baryta offers fewer difficulties. They are precipitated as sulphates.

To separate magnesia from the fixed alkalies, we digest the mixed bases, previously converted into chlorides with carbonate of silver, until the liquid has a strong alkaline reaction. Carbonate of magnesia is thus precipitated. The precipitate containing chloride of silver, with any excess of carbonate of silver and carbonate of magnesia, is digested with dilute hydrochloric acid, which dissolves the latter only, forming chloride of magnesium, which, when concentrated by evaporation, and exposed to a cold atmosphere, yields prismatic hydrated crystals. This salt was formerly termed muriate of magnesia.

CONCHOLOGY.

CHAPTER VII.

TRIBE IV.—MACROSTOMA.

Shells auriform, with the aperture very wide, and the margin disunited; destitute of a columella, or operculum.

Genus.—Pleurotomaria.—*De France.*

Generic Character.—Shell turbinated; for the most part trochiform, usually abruptly conical, in others subturreted; aperture generally subquadrangular, in other species somewhat rounded, considerably flattened, and largely umbilicate at the base; outer lip sharp-edged, furnished with a deep notch at its upper extremity, near the suture.

Pleurotomaria sculpta. Plate V. fig. 6. *P. lirata*, fig. 7.

The Pleurotomariæ having a much deeper fissure, and being destitute of a canal, at once distinguish them from the *Pleurotomæ.* In their general contour they nearly resemble the Trochidæ.

The shells of this genus have only been found in a fossil state. Casts of them have been discovered in a stratum of limestone in Normandy; and they occur in the Kimmeridge Shale, or Oxford Clay, and in the inferior Oolite.

Genus.—Trochotoma.—*Lycett.*

Generic Character.—Shell turbinated, conical; volutions usually angulated, having a band or rib encircling the middle of each volution; periphery subangular; aperture basal, subquadrate; columella curved; base excavated; excavation large, and resembling an umbilicus; fissure transversely elongated, closed anteriorly, but not far from the outer lip, its length being about equal to the distance which separates it.

Trochotoma obtusa. Plate VI. fig. 29. From the great Oolite, Minchinhampton.

The remarkable fissure or opening in the lower volution, at once distinguish the shells of this genus from those of Trochus, to which they bear a strong similarity of form. At first this fissure was considered an accidental perforation.

Genus.—Scissurella.—*D'Orbigny.*

Generic Character.—Shell with a depressed spire, consisting of few volutions; aperture nearly orbicular; lips separated from each other at the upper part on the left side; outer lip sharp on the edge; an oblong foramen near the upper part on the right lip, conforming to the growth of the volutions, placed nearly parallel with the suture, and forming a sort of keel upon the back of the shell; destitute of a canal.

Scissurella concinna. Plate V. fig. 38. *S. crispata*, fig. 37.

The species of this genus are minute, and are chiefly found on the shores of the Mediterranean. One species, however, was found by Dr. Fleming in sand, from Noss, Zetland, after a storm, viz., *Scissurella crispa.*

They have been found fossil in the *Calcaire-grossier* of Grignon, and in fossil sand at Castel Arquato.

Genus.—Stomatia.—*Lamarck.*

Generic Character.—Shell suborbicular or oblong, generally ear-shaped and depressed; pearlaceous within, and usually coloured externally; spire with from two to four volutions, in most species prominent, but not produced nor elongated; in some instances it is very small, marginal, and hardly perceptible; aperture always very large, its margin entire, and united above, longitudinal for the most part, and in some species almost orbicular, in others more elongated, and hardly modified or altered in form by any portion of the body volution; internal cavity marked by two muscular impressions, seldom distant, nearly marginal.

Stomatia inconspicua. Plate V. fig. 19. Found in the mountain limestone, at Bolland.

The above generic character combines the *Stomatia* and *Stomatella* of Lamarck, as neither of these have distinctions

sufficient to entitle them to be separated, and we have followed Sowerby in forming a union between these genera.

All the shells of this genus are marine, and inhabit the East Indian seas, and coasts of New Holland.

This is the only fossil species with which we are acquainted; it is the *Pleurotomaria inconspicua* of Phillips.

Genus.—VELUTINA.—*Fleming.*

Generic Character.—Shell thin, more or less coriaceous, invested with a velvet-like epidermis; volutions few; spire very short; body volution very large and ventricose; with an entire, ample, patulous aperture; outer lip sharp-edged; peritreme continuous; destitute of an operculum.

Velutino lævigata. Plate VI. fig. 30. Found in the Mammiferous Crag, Thorpe, and is a common shell of the British seas.

Genus.—SIGARETUS.—*Lamarck.*

Generic Character.—Shell suborbicular, oblique, ear-shaped, for the most part depressed; spire very small, depressed, consisting of one or two rapidly enlarging volutions, and situate near the margins; aperture entire, large, much expanded, oblique, and longer than wide, with its margins disunited above, in consequence of the outer lip embracing its increment, the lower portion of the body; two muscular impressions within, the one at the upper and the other at the lower end; outer lip smooth on the margin; inner lip spirally twisted, for the most part reflected above, and when largely so producing a small subumbilicus behind.

Sigaretus canaliculatus. Plate V. fig. 2, and Plate VI. fig. 9. Found in the London Clay at Hordwell.

The Sigareti bear a general resemblance to the Stomatæ, but their substance is totally different, those of the present genus being always thick, and never pearlaceous internally; besides, the aperture is always modified by the body, and they are known from *Natica* by the width of their aperture.

The species of Sigareti are few in number, they inhabit the ocean, and are internal or subinternal shells.

Fossil species occur in the London Clay at Barton, and in the contemporaneous formations of Italy and France, also in the *Calcaire-grossier* at Grignon, in France.

Genus.—MARSENIA.—*Leach.*

Generic Character.—Shell internal, convolute, ear-shaped, thin, delicate, fragile, pellucid, and semipapyraceous; consisting of a few rapidly increasing volutions; aperture expanding widely; spire small and depressed; peritreme sharp and thin, confluent with the columella, which is visible internally to the apex of the spire.

Marsenia tentaculata. Plate V. fig. 16. Found in the Coral Crag, Sutton. It is met with in the British seas in a recent state.

Genus.—NATICA.—*Adanson.*

Generic Character.—Shell subglobose, oval, or oblong, umbilicate; spire short, sometimes very short, with the apex very rarely pointed; aperture large, semicircular, and but seldom effuse; outer lip sharp-edged, smooth within; columellar lip oblique, its edge nearly straight, destitute of teeth, generally thickened, and sometimes with a coating of enamel spread thickly over the umbilicus; umbilicus usually large, having a spiral callosity within, which sometimes increases so as to cover it, and is sometimes very small, in a few instances nearly obsolete, so much so as hardly to be perceptible; operculum testaceous in some species, and horny in others.

Natica epiglottina. Plate V. fig. 5.

The species are numerous, and inhabit the ocean, the East and West Indies, Mediterranean, and British coasts.

There are also many fossil species, whose forms bear a remarkable similitude to the recent species, and even some of them retain their colours. They are chiefly met with in the newer formations over the Chalk, more particularly in the Crag, London Clay, and *Calcaire-grossier.*

Genus.—NERITA.—*Lamarck.*

Generic Character.—Shell solid, generally thick, semi-globular, or obovate; spire very short; base of the body, for the most part, flattened beneath, but destitute of an umbilicus; aperture semicircular; outer lip sharp in the margin, and crenulated or toothed on the inner side; inner lip generally flattened, sharp on the margin, which lies oblique to the axis of the shell, and, for the most part, dentated or crenated; a small prominence exists at the lower extremity of the inner lip, between which and the inner lip the small appendage to the operculum slides, as the animal opens or closes the aperture for egress, moving in the same manner as a door on its hinges, when the animal protrudes its body; operculum testaceous.

Nerita aperta. Plate V. fig. 3. Found in the London Clay at Barton, and Cowell Bay, Isle of Wight.

The Neritæ are distinguished from the Neretinæ by the thickness of their shell, the teeth on the margin of the pillar lip, and in being destitute of the thick horny epidermis which invests the Neritinæ; and from *Natica* by the flattened area which is produced by the thickened columella.

The Neritæ are marine shells, and the species are pretty numerous, principally inhabiting the seas of the tropics, and the warmer parts of Europe.

Fossil species are met with in the London Clay, and contemporaneous formations of France and Italy.

Genus.—PILEOLUS.—*Cookson.*

Generic Character.—Shell concave; spire internal, very short; with a subcentral erect vertex; base concave, nearly orbicular, and somewhat cushion-shaped; aperture semicircular, situate in the lower disk, and provided with a crenulated internal lip; external lip furnished with a raised margin.

Pileolus plicatus. Plate V. figs. 43 and 44.

Only two species of this curious genus have been discovered; they are both fossil, and were met with together at Ancliffe, in the coarse upper stratum of the great Oolite, immediately under the Bradford Clay, and have since been found at Charter-House, Hinton, Somersetshire.

Although these shells bear a strong resemblance to Patellæ, their internal concealed spire connects them with the genus Nerita.

Genus.—NERITOPSIS.—*Gray.*

Generic Character.—Shell subglobose, thick and cancellated; spire very small, consisting of three or four rapidly diminishing volutions; aperture entire, transverse, oblique, suborbicular, or ovate; outer lip thickened internally, somewhat grooved and acute on its outer edge; columellar lip thick, rather flat, and provided with a large broad double notch, a little rounded, above the centre of its inner edge.

Neritopsis cancellata. Plate V. fig. 9.

The shells of this genus are distinguished from those of Nerita by that strongly marked character, the notch on the columella.

The Neritopsi inhabit the seas of tropical climates. They have been found fossil in the Tertiary formations at Turin, Bordeaux, and several parts of Normandy.

Genus.—NERITINA.—*Lamarck.*

Generic Character.—Shell thin, external surface generally smooth, and frequently covered with a strong horny epidermis; spire mostly very short, sometimes nearly concealed, and at others obsolete; aperture semicircular; outer lip plain, sharp, and destitute of teeth or crenulations internally, but within the lower region of the aperture it is provided with a somewhat elongated, transverse prominence, which seems the fulcrum for the articulation of the operculum; inner lip flattened and reflected on the columella, and placed obliquely to the axis of the shell; edge generally sharp, and dentated or crenulated; as the animal increases in dimensions, part of the columellar lip is absorbed, which makes it appear as having no columella; operculum testaceous, semicircular, closing the aperture entirely, covered with a horny epidermis, and provided internally, at the lower end, with a tooth-like appendage, which fits into a hollow between the prominence and lip.

Neritina concava. Plate V. fig. 8. Found in the London Clay at Muddiford, and Highgate Hill.

This genus and Nerita are closely allied, and some attention is required to distinguish them. In the Nerita, the inner side of the outer lip is generally provided with numerous transverse teeth, or plicæ, and are, for the most part, stronger shells, being frequently striate, grooved, or tuberculate externally.

The Neritinæ inhabit fresh waters; the species are met with in almost all countries.

They occur fossil in the newer formations above the London Clay, the upper marine formations, and in the Woolwich beds; as also in the same strata of Germany and France.

TRIBE V.—PERISTOMIDA.

Shell conoidal, or subdiscoidal, with the margins of the aperture united, provided with an operculum; animals fluviatile, respiring in water.

Genus.—AMPULLARIA.—*Lamarck.*

Generic Character.—Shell globular, or globularly discoidal, or discoidal and umbilicate; spire short, the volutions ventricose; aperture entire, oblong, oblique, and its length considerably exceeding its breadth; operculum testaceous, annular, with its nucleus nearly central, but placed rather nearer the inner side, and covered by an olive-green horny epidermis, and exactly fitting the aperture.

Ampullaria ambulacrum. Plate V. fig. 39. Found in the London Clay at Hordwell.

Many of the shells of this genus, and those of *Planorbis,* are so similar in external form, that considerable attention is necessary to distinguish them. Lamarck, the founder of the genus, has himself run into error in this respect. The chief difference in the discoidal species and the *Planorbis* consists in the aperture, and in being opercular. The aperture in *Ampullaria* is oblong, entire, and longer than it is wide, and is provided with a testaceous operculum; in *Planorbis* the aperture is always transversely elongated, and destitute of an operculum; besides, their spire is always reversed. The Ampullariæ may also be confounded with the shells of *Natica* and *Helex*, especially when the shells have not the operculum to assist in determining them. They differ from *Natica* in being devoid of the testaceous callosity on the side of the umbilical region; and from *Helex*, in not having a thickened and revolute outer lip.

Several of the species are reverse or heteroclitical shells.

The Ampullariæ inhabit rivers and lakes in tropical climates, and are not numerous.

Fossil species have been found in the *Calcaire-grossier* near Paris; at Hordwell in the London Clay; and in the fresh water formation at Headon Hill, Isle of Wight.

Genus.—PALUDINA.—*Lamarck.*

Generic Character.—Shell ovate or oblong; spire somewhat turreted; the volutions smooth, rounded, and subcarinated; aperture subrotund, ovate, or oblong, a little angulated above, slightly modified on the inner side by the gibbosity of the body volution; operculum corneous, with concentric lines of growth, and provided with a sublateral nucleus.

Paludina Desnayarsii. Plate V. fig. 12.

In some species the spire is much depressed. The Paludinæ are somewhat allied in form to the genera *Ampullaria*, *Valvata*, and *Cyclostoma.* They differ from *Ampullaria* in having a horny operculum in place of a testaceous one, as also in their general form; and they are distinguished from the two latter genera by their concentric operculum, whereas theirs is spiral.

The species of this genus are not numerous, and inhabit lakes and rivers in almost all tropical and temperate climates.

In a fossil state they abound in a thin stratum immediately over the upper fresh water formation at Headon Hill, and are the chief molluscs in the Petworth Marble.

Genus.—VALVATA.—*Müller.*

Generic Character.—Shell turbinated or discoidal, thin, corneous, or semitransparent; teeth much rounded, nearly cylindrical, volutions not impressed by the preceding one; generally smooth, covered with a corneous epidermis; aperture circular, with a sharp continuous peritreme, not reflected; operculum concentrically spiral.

Valvata piscinalis. Plate VI. fig. 37. From the Mammiferous Crag at Bramerton.

The shells of this genus inhabit fresh water, and are found in most parts of the world, chiefly in lakes, ponds, and ditches.

TRIBE VI.—MELANIDES.

Fluviatile shells, with the margins of the operculum disunited, and the right one acute at the edge; animal furnished with two tentacula.

Genus.—MELANOPSIS.—*Ferussac.*

Generic Character.—Shell oblong, fusiform, or conico-cylindrical; spire with from four to fifteen volutions, terminating in a pointed apex, but decollated in some species; body frequently equal to two-thirds of the whole shell; aperture oblong-ovate, pointed at the upper extremity; outer lip somewhat thickened and slightly inflected, and deeply notched above; columella twisted, solid, callous, and separated from the exterior margin at the base, by a deep sinus in most species, but devoid of it in some; callosity thickest at its junction with the upper extremity of the aperture; operculum spiral, corneous, and not quite fitting the aperture.

Melanopsis carinata. Plate V. fig. 36. Found in Greensand, Isle of Wight.

The apex in the shells of this genus is very subject to erosion, seldom being met with complete.

The Melanopsi inhabit lakes and rivers; the species are but few, and are confined to the fresh waters of India, Africa, and the South of Europe.

In speaking of this genus, Baron d'Audebard De Ferussac says, "The genus Melanopsis is one of the most interesting of the Mollusca, in consequence of the important facts proved by its fossil species, in connection with the history of the Tertiary formations. It equally merits attention in a zoological point of view, because it exhibits a kind of transition from the operculated to the semi-operculated Pectinibranchia; that is, from those Pectinibranchia whose shells are furnished with an entire aperture, without a canal at its base, and whose operculum entirely covers the aperture, to those with a more or less distinct canal at the base of the aperture, destined to receive a fold of the mantle, which conveys the water to the branchial cavity, and whose operculum is neither so large nor of the same form at the aperture."*

The fossil shells of the genus Melanopsis are invariably found associated with species which inhabit fresh waters, and it may be, therefore, considered as certain, that the strata in which they are found belong to the fresh water formation.

Genus.—MELANIA.—*Lamarck.*

Generic Character.—Shell turreted or subturreted; spire for the most part elongated, with the volutions divided by a deep suture, and generally terminating in an acute apex; aperture entire, oval or oblong, in most species acuminated at the superior extremity, and rounded below; with an indistinct canal at the base of the columella; outer lip simple and somewhat sharp; columella smooth and incurved; outside covered with a strong horny, olivaceous, brown or black epidermis; operculum horny, oblong, spiral, with two or three volutions.

Melania costellata. Plate VI. fig. 3.

In some few instances the upper part of the aperture is separated from the body; sometimes they are externally smooth, but for the most part they are grooved, tuberculated, or granulated, at others, with spinous granulations.

The Melaniæ are all fresh water shells, inhabiting the rivers of warm countries; and the species are not numerous. They are very subject to erosion in the superior volutions, and frequently so much so, that the apex and some of the upper volutions are entirely decomposed, to such an extent as to render it completely truncated.

In general form the Melaniæ bear a strong resemblance to

* De Ferussac, "Memoirs de la Société d'Historie Naturelle de Paris, 1807, p. 133.

the Turitellæ, but the orbicular aperture of the latter, and being devoid of an epidermis, will at once distinguish them; they are also somewhat allied to the shells of the genus *Terebra*, but attention to the distinct canal of the latter will render their difference obvious.

Fossil Melaniæ are plentiful in the fresh water formation at Headon Hill, Isle of Wight, Charleton, near London, and in the same kind of formation in Normandy, and vicinity of Paris.

Genus.—Pasithæa.—*Lea.*

Generic Character.—Shell pyramidal; body and spire about equal in length, tapering to an acute apex, the volutions being flat-sided; aperture oblong-ovate, contracted above, and terminating in a very short canal below; outer lip thin, and not reflected.

Pasithæa striata. Plate V. fig. 41.

The shells of this genus are known only in a fossil condition, and occur in a marine formation, North America.

TRIBE VII.—LYMNÆCEA.

Shells spiral, generally smooth on the external surface; margin of the outer lip always acute, and not reflected. The animals of this tribe are amphibious, and usually destitute of an operculum.

Genus.—Lymnæa.—*Lamarck.*

Generic Character.—Shell oblong, thin, sometimes elongated, and acutely turreted; spire always produced; aperture large, entire, oblong, generally straitened and somewhat acuminate above, and rounded below; outer lip acute; the lower part of the inner lip ascending on the columella, forming an oblique plait or fold, and rising, spreads more or less over the columella or front of the body volutions; external surface smooth, frequently polished; destitute of an operculum.

Lymnæa pyramidalis. Plate VI. fig. 4. Found in the fresh water formation of Headon Hill, Isle of Wight.

We cannot concur with Sowerby in uniting the genus *Physa* with the present, nearly allied as they unquestionably are; the circumstance of the convolutions of the spire being invariably reversed or heterostrophe, proves that there must be a distinct conformation in the animals.

The genus Lymnæa may be subdivided as follows:—

Section 1.—Shells oblong and turreted. L. stagnalis and its congenerous species.

Section 2.—Shells greatly elongated. L. elongata, &c.

The shells of this genus inhabit ditches, ponds, lakes, and rivers, in almost all countries.

Fossil species occur in the fresh water formations in the vicinity of Paris, and at Headon Hill, Isle of Wight.

Genus.—Succinea.—*Drapernaud.*

Generic Character.—Shell very thin, ovate, elongated; body very large, spire rather small; volutions few; covered with a thin corneous epidermis; aperture large, oblong, oblique; peritreme thin and disunited.

Succinea putris. Plate IV. fig. 38. Found in the Mammiferous Crag, Bramerton.

This is a fresh water genus, the species are found on the margins of ponds, ditches, and rivers, generally adhering to the stems of aquatic plants. They approach in general form to those of the genus Lymnæa, but are devoid of an oblique fold, which exists in a greater or less degree upon the columella of the Lymnæa.

Genus.—Physa.—*Lamarck.*

Generic Character.—Shell sinistral, very thin, polished, and transparent; body somewhat longer than the spire, which consists of a few reversed volutions; aperture oblong; inner lip spread over the columella; outer lip very thin, but not reflected; destitute of an operculum.

Physa columnaris. Plate VI. fig. 11. Found fossil in the new formation at Epernoy, France.

The shells of this genus inhabit fresh waters in all temperate climates; they are exceedingly thin and delicate; and are at once distinguished from the Lymnæa, by the convolutions being reversed.

Genus.—Planorbis.—*Müller.*

Generic Character.—Shell discoidal, umbilicate; spire and base depressed; apex always distinct; the volutions turning nearly on the same plane from right to left, so that when the spire is held upwards, and the aperture next the observer, it is situate on the left-hand side; volutions ventricose in many species, often carinated, either above or below; aperture entire, obliquely semilunate, its length and breadth being nearly equal, but broader than long in some instances; outer lip sometimes thickened; umbilicus very wide; destitute of an operculum.

Planorbis rotundatus. Plate VI. fig. 10. Found in the London Clay, at Hordwell Cliff.

Section 1. Volutions not carinated, rounded both above and below; the spire flattened, and slightly concave. Example, *P. rotundatus.*

Section 2. Carinated, volutions flat above. Example, *P. marginatus.*

Section 3. Pellucid, spire deeply umbilicate; volutions slightly carinated, and lenticular. Example, *P. nitidus.*

The upper side or apex of the shells of this genus is that in which the volutions terminate in the centre, generally in a point, with the aperture next the left hand; the umbilicus will be found on the opposite side.

The shells of this genus are found in stagnant waters, ditches, lakes, and also in slow running streams. Their geographical range seems limited to Europe and America, and those of the latter country have a thickened lip.

Fossil species are found in the fresh water formations at Paris and the Isle of Wight.

TRIBE VIII.—COLIMACEA.

Shell spiral; external surface smooth, exhibiting only the lines of growth; right margin of the aperture frequently reflected outwards; animals terrestrial, with cylindrical tentacula; some species with an operculum, and others devoid of one.

SUBDIVISION I.—Animals with two tentacula.

Genus.—Cyclostoma.—*Lamarck.*

Generic Character.—Shell thin, turbinated, variable in shape, the apex in most species obtuse, and the volutions ventricose; aperture entire, circular, or nearly so, in the adult state; peritreme, or outer lip, more or less angular at the upper parts, united all round, sometimes thickened, usually reflected, and frequently externally fringed; operculum spiral, generally horny, but inclining to testaceous in some species; consisting of a few depressed convolutions, provided with a simple testaceous internal coating.

Cyclostoma antiqua. Plate V. fig. 40.

Several of the species approach nearly in form to the Paludinæ and Valvatæ, but the orbicular aperture and entire outer lip at once distinguish the Cyclostomata from the shells of these genera, independently of their being fluviatile.

The Cyclostomata are all land shells, and the species very numerous, amounting to about ninety. They chiefly inhabit India, the West Indies, and South Sea Islands; a few are natives of Europe, and three are found in Britain.

Various species are known in a fossil state, and these are only met with at Grignon in the Calcaire-grossier.

Genus.—Nematura.—*Benson.*

Generic Character.—Shell thin, almost oval, a little compressed from back to front; body large, contracted near the aperture; spire small, consisting of few inflated volutions terminating in an acute apex; aperture small, oblique, rounded below, and a little contracted above; outer lip continuous and thin; operculum horny, spiral, with few convolutions.

Nematura deltæ. Plate V. fig. 45.

A distinguishing character of the shells of this genus is the contraction of the body volutions near the aperture. They are all very minute.

The Nematuræ are marine shells, and but two recent species are known. One fossil species only has been discovered.

Genus.—RINGICULA.—*Deshayes.*

Generic Character.—Shell solid, oval, or oblong-ovate, cylindrical or conic; body large, spire very small, obtuse; aperture narrow, generally contracted near the centre, and rounded below; inner lip with two or three strong plaits; outer lip thickened, reflected, or denticulated; covered with a horny epidermis.

Ringicula ventricosa. Plate IV. fig. 12. Found in the Crag at Ipswich.

The Ringiculæ are marine shells, and are found in the warmer countries of the globe. The species are very limited in number.

Fossil species are rare, and are met with in the newer formations.

SUBDIVISION II.—Animals provided with two tentacula.

Genus.—BULIMUS.—*Bruguière.*

Generic Character.—Shell oval or oblong, generally thin, and covered with a slender epidermis; spire obtuse, variable in length and number of its volutions, which, for the most part, are few; aperture oval, wide, anteriorly rounded; outer lip simple, reflected, continuous, and joining the columellar lip without an emargination, and reflected over part of the body; columella smooth, straight, without a truncature, or widening at the base.

Bulimus costellatus. Plate VI. fig. 6. *B. cylindracea.* Plate V. fig. 46. The former is from the fresh water formation, Isle of Wight.

The Bulimi are distinguished from the Achatinæ by being destitute of the notch at the junction of the outer and pillar lips. They are land shells, the species are numerous, and inhabit almost all countries.

Fossil species are only met with in the fresh water formations.

Genus.—AGATHINA.—*Deshayes.*

Generic Character.—Shell oblong-ovate; smooth and polished, body and spire nearly of equal length; volutions inflated, and terminating in an acute apex; aperture oblong, narrow, contracted above, and truncated below; outer lip acute, but never reflected.

Agathina pellucida. Plate VI. fig. 2. Found in the Calcaire-grossier at Paris.

Known only in a fossil state.

Genus.—HELIX.—*Linnæus.*

Generic Character.—Shell orbicular, thin, subglobose; body very large, spire short, and small in proportion to the body; aperture oblique; outer lip reflected, and interrupted by the bulging of the body; columella confluent with the outer lip, and situate on the lower portion of the axis; destitute of an operculum.

Helix turtonensis. Plate VI. fig. 22. Found in the Calcaire-grossier.

The Helices are land shells, and have been met with in almost all portions of the world. The genus is very comprehensive, and may be divided into the following sections:—

Section 1. Body large, and destitute of an umbilicus. Example *Helix aspersa.*

Section 2. Body large, provided with an umbilicus at the base.

Section 3. Body large, outer lip thickened, and provided with teeth. Example, *Heiix nux denticulata.*

Section 4. Body very large, carinated; spine short, conical, and depressed. Example, *Helix lapicida.* Caracolla lapicida of Lamarck.

The Baron De Ferussac has united the following genera under the generic name Helix, namely, Helix, Bulinus, Clausilia, Achatina, Anastoma, Lapicida, Azeca, &c. These he has again formed into sub-genera.

Genus.—STROPHOSTOMA.—*Deshayes.*

Generic Character.—Shell pyramidal, depressed; body very large; spire very small, consisting of few rapidly diminishing volutions; base of body nearly flat, with a carinated margin, and provided with a pretty large and deep umbilicus; aperture sublunate, and obliquely turned upwards towards the spire; lips entire; provided with an operculum.

Strophostoma ferussina. Plate VI. fig. 18.

This is exclusively a fossil genus, and closely connected with *Anostoma*, but is distinguished from that genus by being umbilicated.

PHRENOLOGY.

CHAPTER XIV.

INTELLECTUAL FACULTIES—CONTINUED.

30. EVENTUALITY.—Dr. Gall admits both in man and animals a peculiar organ of Educability, or of the Memory of things and events. Daily we meet with individuals possessing a general knowledge of the arts and sciences, and who, without being profound, know sufficient to be capable of speaking on them with facility; individuals who are deemed clever and brilliant in society. The middle part of their foreheads Dr. Gall found was very regularly prominent. At first he called the cerebral part in the above situation, the organ of "the Memory of things," because those largely endowed with it were commonly well informed, and knew a great deal; he afterwards named it "the sense of things." In comparing animals with man, and one species of animal with another, he found that tame have fuller foreheads than wild animals, and that animals are generally tameable, as the forehead is more largely developed; he therefore, afterwards, called it the organ of Educability. Dr. Spurzheim objects to this name, as every faculty may be educated; or, in other words, exercised and directed; consequently, he has named it Eventuality.* It enters into a large share of the business of actual life; it takes cognizance of things past or present; it confers an aptitude for anecdote, and a general facility for the acquisition of the principles of science and philosophy. It is also powerful in aiding the memory, and bringing forth at seasons most necessary, those felicitous illustrations, which carry as it were conviction with them. Memory is to the mind what a storehouse is for goods, preserving all kinds of merchandise, that it may meet every emergency of the market, and thus be able to compete with all. In the person of the celebrated Magliabechi, who was considered a prodigy of learning, this faculty was strikingly exemplified, as will be exemplified by the following anecdote:—"A gentleman, of Florence, having written a piece, which he intended at a future time to publish, lent the manuscript to Magliabechi for his perusal, who returned it to the author with many thanks. Some time after, the writer with a melancholy countenance came to Magliabechi, and told him of some invented accident, by which he said he had lost his MS., and entreated Magliabechi—whose character for remembering what he read was already very great—to try and recollect as much of it as he possibly could, and write it down for him against his next visit. Magliabechi assured him that he would do so, and setting about it, wrote down the whole MS., without missing a word, or even varying, according to his biographer, anywhere from the spelling." In this case, there must have been great Locality, and Form, as well as Eventuality, and Language. Individuality must, likewise, have been largely developed. Of his Locality, it is stated that he could not only lay his hand on a book that he might want, momentarily, but could direct any other person with such minuteness of detail, to the very spot where a book was to be found, that filled all persons with astonishment at the extent of his powers of memory. Of his Individuality, Form, and Language, we have an instance in the anecdote just narrated, that he wrote down the whole of the piece without varying from the spelling, &c. But Eventuality seemed to be the predominating power, and, it accordingly lent its aid to those other faculties that were fully developed. This person left his library to the public; the bare catalogue of which filled 3 vols. folio. He died in 1714. An instance of

* Spurzheim's Phrenology.

Eventuality, associated with Language, is recorded of Joseph del Castello, a Spaniard; of him it is related that he knew the whole Bible by heart, and could repeat the entire works of Seneca with the utmost facility. He was frequently employed by Philip the Second of Spain, and always acquitted himself with probity and conscientiousness. The faculty of Eventuality is indeed a noble one, it seems to influence and enter into more or less all the others. The five senses appear but as its servants. It teaches the eye to descriminate; the ear to delight in the harmony of sweet sounds; it gives gustativeness to the taste; it guides and sways the feelings, and gives to the perceptive faculties those delicious odours which we meet with in a garden of richly perfumed flowers. It is highly essential to a man of letters. I should not think that judicious selections could be made from the works of others without it; therefore it will be useful for an editor of a periodical work. It is highly indispensable to a secretary, giving great facility of reference. To the historian, whose knowledge of events must not only be extensive, but accurate, it is essential in the highest degree. To the teacher, it will impart that peculiar tact which will enable him to extract a lesson from every fact that presents itself. To the botanist it is also highly necessary, and in short there seems to be neither scientific or philosophic system but that comes within the sphere of its operation. When in too great a degree of activity, it is liable to expend its energies on trifles and useless acquisitions, and degenerates into restlessness and gossip upon the passing events of the day. It is, in such case, closely allied to the propensity of the Athenians, who spend their time in nothing else but to hear and to tell some new thing.

Haslitz, in his contemporary portraits, thus describes Sir James Macintosh:—" There is scarcely an author that he has not read; a period of history that he is not conversant with; a celebrated name of which he has not a number of anecdotes to relate; an intricate question that he is not prepared to enter upon, in a popular or scientific manner. If an opinion in an abstruse metaphysical author is referred to, he is probably able to repeat the passage by heart; can tell the side of the page on which it is to be met with; can trace it back through various descents, to Locke, Hobbes, Lord Herbert of Cherbury, to a place in some obscure folio of the schoolmen, or a note in one of the commentators of Aristotle or Plato, and thus give you in a few moments' space, and without any effort or previous notice, a chronological table of the progress of the human mind in that particular branch of enquiry. This is the result of very large Causality, Eventuality, Locality, and Language. Brougham, is thus described by the same author:—There are few intellectual accomplishments that he does not possess, and possess in a very high degree. He speaks French and several other modern languages fluently; is a capital mathematician, and obtained an introduction to the celebrated Carnot in this latter character, when the conversation turned on squaring the circle, and not on the propriety of confining France within the natural boundary of the Rhine.

31. Time.—Above the centre of the eyebrow, directly over Colour, is situated the organ of Time. This is a distinctly different organ from those of Order and Number, its functions being more properly to give the idea of duration, than strictly to take cognizance of exact numbers, or of orderly arrangement. It is essential to all persons. To the musician it is highly useful—it gives that just and accurate duration to the several parts of a piece of music, which so essentially contribute to the power of the harmony. We do not, however, find it unusual to meet with persons who have what is called a good musical ear—in phrenological language, a good organ of Tune; but who, nevertheless, are so sadly deficient in Time, as to be totally unfit for performing in a concert. This was the case with Paganini, who, though the most celebrated violinist that perhaps ever lived, was yet sadly deficient in Time. Some persons judge with exceeding exactness in regard to time. In the phrenological analysis of Campbell (the murderer), Time was so large, that the individual who indicated his character assumed that he would probably be able to tell the hour without the aid of a clock or watch, and this has, to a degree, been proved correct. On the contrary, in a similar analysis by Mr. Simpson of the cast of a gentleman, he mentions a want of punctuality of appointments, owing to a deficient perception of the lapse of time. This the gentleman acknowledges to be true: observing—"Appointments I never on any occasion wilfully break, as I consider the thing dishonest; but I sometimes, or rather frequently do so from forgetting them, or from forming a wrong estimate of time. I can make nothing of time unless I have my watch. I have seen me, when my watch was mending, mistake 3 o'clock P. M. for noon, and *vice versa*."

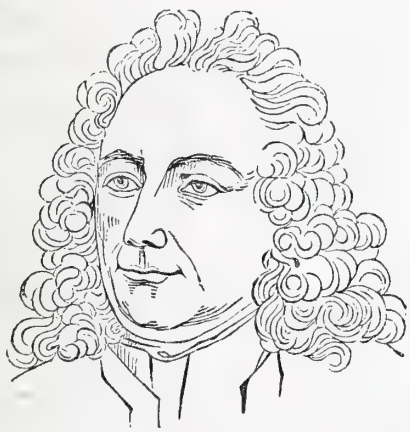
To the poet, the faculty of Time imparts a knowledge of that harmonious duration, which gives, what is technically termed, the exact number of feet, *i.e.* of syllables in a line. This regularity is particularly observable in the compositions of Pope and Wharton. In blank verse poets, as Milton, there is a frequent closing of a stanza with a line, which either contains one or two less, or one or two more syllables than the strict measure of time will allow. This, however, is only tolerated where the sense would be incomplete without it, or where the verse is acknowledged as irregular—Rogers is an instance of this innovation on the order of time. The organ is useful to the orator, and marks the necessary gradations for emphasis, pause, and cadence. To the Christian, the faculty is also indispensable. The duration of his existence in this world is but seventy years, and, as he believes in divine revelation, he should take due heed to the lapse of time; as he knows that every hour brings him nearer to eternity, he should endeavour constantly to improve it. It should never be absent from his remembrance, that time is but the germ of eternity.

"Time is the germ of being. When the soul
Emerges from this chrysalis of clay,
In uses of delight shall ages roll,
And wisdom's brighter sun illume th' eternal day.
Sad is the lapse of time, should evils reign
And conscience sleep beneath their tyrant sway;
Should virtue's gentle whispers plead in vain
Till angels turn reluctantly away.
Sad is the eternal view, when life's short round
The reckoning swells of folly and of sin;
When not a ray of hope on earth is found,
And misery must with endless life begin:
Hail, then, religion's laws in early prime,
And sweet in age shall prove the lapse of time."

In the Library of Entertaining Knowledge, vol. i. page 55, it is proved that, to a certain degree, many of the inferior animals have a distinct knowledge of time. The sun appears to regulate the motions of those which leave their homes in the morning, to return at particular hours in the evening. The Kamtschatka dogs are probably influenced in their autumnal return to their homes by a change of temperature; but in those animals possessing the readiest conceptions, as in the case of dogs in a highly civilized country, the exercise of this faculty is strikingly remarkable. Mr. Southey, in his Omniana, relates two instances of dogs, who had acquired such a knowledge of time as would enable them to count the days of the week. He says: "My grandfather had one which trudged two miles every Saturday, to cater for himself in the shambles. I know another very extraordinary and well-authenticated example. A dog which had belonged to an Irishman, and was sold by him in England, would never touch a morsel of food on Friday. The same faculty of recollecting intervals of time exists, though in a more limited extent, in the horse. We knew a horse (says the editor of the Manageries), and have witnessed the circumstance, which, being accustomed to be employed once a week by a newsman of a provincial paper, always stopped at the houses of the several customers, although they were sixty or seventy in number. If the sagacity of the horse had stopped here, we should say this has nothing to do with time, but indicates more of locality. But the knowledge of time consists in this. There were two persons on the route who took one paper between them, and each claimed the privilege of having it first on the alternate Sunday. The horse soon became accustomed to this regulation, and although the parties lived two miles distant, he stopped once a fortnight at the door of the hal customer at Thorpe, and once a fortnight at that of the other half customer at Chertsey; and never did he forget this arrangement, which lasted several years, or stop unnecessarily when he once thoroughly understood the rule." In

the Phrenological Journal (vol. viii., p. 76), there is another remarkable relation of the knowledge of time possessed by animals. "My brother (says the writer) has a bitch of the name of Quelo, which unequivocally manifests the power of remembering the days of the week. On Saturdays, it is my brother's practice to go out to walk or shoot, and on these occasions he generally takes Quelo along with him. From Monday to Friday her outgoings and incomings seem to be regulated by no certain rule. On the Saturday morning, however, she is observed to indulge much in sleep, and to be careful to go very little out of doors. Towards noon, the time when her master usually comes home, she evinces a growing impatience, and at first places herself in the middle of the kitchen floor, pricks up her ears, and listens with the most eager attention to every footstep. Being, on a particular occasion, confined to a remote part of the house for several days, she, of course, manifested her dislike to her situation by yelping and barking, but when Saturday arrived, and the usual hour glided past without her master making his appearance, her cries became louder and more incessant than on any other day. It will, perhaps, be insinuated that this knowledge of Saturday may be derived from the observation of domestic operations peculiar to that day; but as these operations have, in the present instance, nothing peculiar about them, the argument is untenable. Besides, how could the animal know what was taking place in the house on the day she was chained in the cellar?"

Where the faculty is in too active a state, it is frequently irritable and restless; and where it is deficient, it gives rise to dilatoriness and procrastination.



32. Melody or Tune is situate over the organs of Order and Number, towards the lateral part of the forehead between Time and Construction.

Some persons are so instantly arrested by music played in the street, that they find it almost impossible to leave the spot whence the sounds emanate, until the whole of the piece is played through. Others will pass by during the performance of the most exquisite strains, and be not at all affected by what many would term the most *soul-subduing harmony*.

Some pupils who have been placed under the care of music masters learn almost intuitively; others, with the utmost labour and diligence, can never compass a single tune. Music masters have evidenced the truth of this hundreds of times.

We once had under our care at Bristol a deaf and dumb pupil, who had a very large development of Tune, and manifested extreme anxiety when it was pursued in the regular business of the school. By the mere motion of the lips as he perceived it in ourself, he had acquired one tune perfectly, and gave utterance to it in low, plaintive, and not inaccurate sounds. He was considered as a prodigy amongst us, and many were the individuals that came to hear the dumb boy hum a tune; of course there was no articulation, and indeed at that time no knowledge of words. This shows that music is an independent and primitive power, and does not depend upon any of the other faculties; but this was never known until phrenology, as a science, was promulgated by Gall.

The functions of this organ produce a desire for melody or tune, and of all the delightful arts that tend to throw a charm over man's chequered state of being, music is certainly one of the most powerful. It seems wonderful there should be any persons who object to it—such, for instance, as the Quakers; but this could never be, unless there were a deficiency of cerebral organization; and this, if persons will take the opportunity of observing the generality of Quakers, will be found the case; the lateral parts of the forehead are in many of them quite flat, and in some absolutely hollow. This is not, however, the case with all: we knew a young Quakeress in Bristol in 1825, who was an excellent performer on the guitar, and another elderly one of Liverpool in 1827, who was one of the sweetest singers we had ever heard, and as she attended the girls in a large school that we superintended, we had the gratification of frequently hearing her sing. In both these ladies the organ of music was full, but they exercised it in direct violation of an express law of the Society of Friends. We have no doubt but this law originated in the founder, George Fox, through an excessive development of Conscientiousness, supposing that there was more gratification to the creature, than real praise to the Creator, at least in most instances of the use of music. Should phrenology make way among the Society of Friends, as it is sure to make way everywhere in time, there is no doubt but that they will use the organ of music without abusing it, and thus gratify both conscience and order at the same time, while they give proper latitude to music.

When the Scottish people removed the errors of Popery from their churches, they appear to us to have committed a great error in the removal of instrumental music. That noble instrument, the organ, whose united grandeur and volume peals the note of praise upon the ravished ear, is more likely to infuse a feeling of deep and fervent devotion of high and holy veneration, of solemn awe and humble gratitude, than the tones which we sometimes hear from even the most gifted precentors.

It is useless to say to men of this description, that the psalmist exalts the Divine Being in praise upon different instruments; they will not hear of them. The papists have used them, and that with them is sufficient for their rejection. The national characteristic of cautiousness is here strongly predominant; but we are of opinion that this cautiousness is in the present instance carried to excess. Firmness seems also sufficiently to have assisted cautiousness. The fear lest any of the abominations of Popery should again creep into the church, may have been a principal cause for the exercise of caution in this respect; but we humbly submit, what we have on other occasions advanced, that cautiousness may become *abject fear*, and firmness may degenerate into downright *obstinacy*.

The beneficial tendency of music is established in hundreds of instances. In Sir Henry Halford's Essays, he thus describes it:—"I have witnessed its power to mitigate the sadness of seclusion, in a case where my loyalty as a good subject, and my best feelings as a man, were more than usually interested in the success of my patient; and I also remember its salutary operation in the case of a gentleman in Yorkshire many years ago, who was first stupified, and afterwards became insane, on the sudden loss of his property. This gentleman could hardly be said to live—he merely vegetated; for he was motionless until pushed, and did not speak to, or notice anybody in the house for nearly four months. The first indication of a return of any sense appeared in an attention to music played in the street; this was observed, the second time he heard it, to have a more decided effect in rousing him from his lethargy; and induced by this favourable omen, the sagacious humanity of his superintendent offered him a violin. He seized it eagerly, and amused himself with it constantly. After six weeks, hearing the rest of the patients pass by his door to their common room, he accosted them—'Good morning to you all, gentlemen, I am quite well, and desire I may accompany you.' In two months more, he was dismissed cured. Its powerfully soothing properties are also detailed in the sacred scriptures, which would

hardly have been the case had the scriptures prohibited its use. David played upon the harp when the evil spirit was upon Saul, and felt relief himself from the cares of royalty in the harmony of its strings, in the melody he drew from them, and in the psalms of praise, to which both himself and his harp were consecrated. The celebrated philosopher, De Luc, was also soothed by music in his severest sufferings. He had a piano in his bed-room, which his daughter constantly played upon. Observing him one day very weak, and inclined as she thought to sleep, she asked him if she should desist: 'Play on,' said the invalid. He slept, but awoke only in that sphere where the harmony is of the divinest character."

Of the power of music even over the inferior animals, many anecdotes are related. The rude music of the snake-charmers seems to disarm those reptiles for the time of their venomous fangs. A French officer, during his confinement in the Bastile, amused himself by playing on the lute. He had long diverted his melancholy in this way, when one day, as he was playing, he observed, to his great astonishment, a number of mice issuing from their holes, and even spiders creeping forth from their webs; he repeated the experiment with success several times, and he found entertainment in observing how attentive an audience he could summon at his pleasure. We have no reason to conclude that this officer was an Orpheus, yet it is quite certain that he captivated animals who might be supposed insensible to the concord of sweet sounds.

From these effects of the power of music, its cultivation as a distinct branch of education would no doubt be attended with the best and happiest results. In a late number of Chambers' Journal this is warmly recommended, and the example of the working classes of Lancashire and Yorkshire is held up to the imitation of the people of Scotland in the same walks of life. Some excellent observations on the cultivation of music may be found in a little work, lately published, on Domestic Education:—"Let it be carefully instilled," says the author, "into the minds of young persons of either sex, that a moderate knowledge of music, with accuracy and taste, produces more gratification to the listener as well as to the performer, than the greatest brilliancy of touch and rapidity of execution without taste and accuracy. A girl of very moderate musical talent may play or sing to please her relatives and friends, the only persons she ought to desire for auditors, without those fine Italian graces, which, however they may be tolerated in professional singers, reflect but very little credit upon those who play only for amusement.

Music has been given by our bountiful Creator to assist in smoothing the path of human life. The same Being who has covered the face of nature with bright and beautiful colours, has filled the air with sweet and expressive sounds. He has taught us to listen to the melody of the birds, the sighs of the passing breeze, and the accents of the human voice, with feelings akin to those with which we gaze on the glorious heavens, the verdure of the woods, and the meadows enamelled with a thousand flowers. And he has taught us, too, to make our sense of the beauties of nature, derived from the eye or the ear, the foundation of two exquisite arts, by which not only our perceptions of these beauties are quickened and enhanced, but our intellectual and moral qualities are called into action.

Painting and music perform much higher parts than that of merely ministering to human pleasure.

It was the opinion of Dr. Rush, that singing by young ladies, whom the customs of society debar from many other kinds of healthy exercise, should be cultivated not only as an accomplishment, but as a means of preserving health. He particularly insists that vocal music should never be neglected in the education of a young lady; and states, that besides its salutary operation in soothing the cares of domestic life, it has a still more direct and important effect.

"I here introduce a fact," says Dr. Rush, "which has been suggested to me by my profession; that is, the exercise of the organs of the breast by singing, contributes very much to defend them from those diseases to which the climate and other causes expose them. The Germans are seldom afflicted with consumption, nor have I ever known more than one case of spitting blood amongst them; this, I believe, is in part occasioned by the strength which their lungs acquire by exercising them frequently in vocal music, which constitutes an essential branch of their education"

"The music master of our academy," says Gardiner, "has furnished me with an observation still more in favour of this opinion. He informs me that he has known several instances of persons strongly disposed to consumption, restored to health by the exercise of the lungs in singing." In the establishment of infant schools for children of three and four years of age, everything is taught by the aid of song. Their little lessons, their recitations, their arithmetical counting, are all chanted; and as they feel the importance of their own voices when joined together, they emulate each other in the power of vociferating. This exercise is found to be very beneficial to their health. Many instances have occurred of weakly children of two or three years of age, who could scarcely support themselves, having become robust and healthy by this constant exercise of the lungs; these results are perfectly philosophical. Singing tends to expand the chest, and thus increase the activity and power of the vital organs.

William Byrde, one of the greatest musicians of the Elizabethan age, in his preface to his "Collection of Psalms, Sonnets, and Songs of Sadness and Pietie," published in 1598, gives the following reasons for learning to sing, the amusing quaintness of which is mingled with good sense:—

1. It is a knowledge easily taught and quickly learned, when there is a good master and an apt scholar.

2. The exercise of singing is delightful to nature, and good to preserve the health of man.

3. It doth strengthen all the parts of the heart, and doth open the pipes.

4. It is a singular good remedy for stuttering and stammering in the speech.

5. It is the best means to preserve a perfect pronunciation, and to make a good orator.

6. It is the only way to know when nature has bestowed a good voice, which gift is so rare that there is not one amongst a thousand that hath it, and in many that excellent gift is lost, because they want an art to express nature.

7. There is not any instruments of music whatever, comparable to that which is made of the voices of men and women, where the voices are good, and the same well sorted and ordered.

8. The better the voice is, the meeter is it to honour and serve God therewith, and the voices of men and women are chiefly to be employed to that end.

"Since singing is so good a thing,
I wish that all would learn to sing."

At a meeting of the Phrenological Society at Paris, some years since, M. Follati, the president, made some curious demonstrations on the plaster cast of the head of Bellini, taken the morning after the death of that young and eminent composer. From the observations of the learned Doctor, it would appear that the strong feeling and expression which characterized the inspirations of the author of Norma, is to be attributed to the organ of Benevolence, which was largely developed. He ascribed the graceful *nonchalance* and sweet soft delicacy of his airs, to the smallness of his organs of Courage and Firmness. If rhythm was generally the deficiency of all others in the composer's works—if the melodious expression is brief, and appears to want breath, he considered it was to be attributed to the organ of Time, or the faculty of embracing many objects at once, which organ was also very slightly developed. This deficiency was followed by another equally remarkable in the Doctor's opinion, viz., the organ of Construction, which indicates dexterity of fingers. And, in fact, it is well known that Bellini was very *mal-adroit* at the piano, even when playing his own compositions.

The organs of Time and Construction are, on the contrary, much more developed in Paer, Rossini, and generally in all geniuses possessing the powerful talent of rhythm and harmony.

The bust of Paganini supplied M. Follati with facts not less interesting than the foregoing. The organ of Music, he stated, was developed to the fullest extent, as well as the *tactivitie* or firmness of touch evinced in his fingering the strings. The

organ of Tune is deficient, which accords with the remark often made, that this prince of fiddlers was very neglectful of the strict rules of harmony.

MR. G. NASMYTH'S PATENT GIRDERS & FIREPROOF FLOORS.

BY SAMPSON LLOYD, ESQ., OF WEDNESBURY.

This invention relates to the construction of girders, fireproof flooring, roofing, &c., and consists in the novel adaptation of the bow and string principle to the various objects required. The methods adopted in the construction of the several works to which the invention is applicable may be classified as follows:—

1.—As applied to fireproof floors for buildings.

The size and probable weight that the floor will be required to bear being ascertained, plate-iron is taken, of the required size and strength, and is bent in the form of an arch; and another plate is taken for the under side, which is turned up at each end, taking care that the space left between the turned-up ends is of such a length as to retain the upper plate in its bent form. This bottom plate is not required to be of the width of the top plate, unless an even surface is wanted—a strip of bar-iron or steel of the required strength will answer the purpose; neither is it absolutely requisite to have the top plate of the form of an arch, as represented at fig. 1. When the top plate is bent and placed within the turned-up ends of the bottom plate, it is ready for fixing between the wall beams or girders. In all cases the under plate or tension bar should, to secure perfect safety, be of double the strength that is estimated to be requisite.

The entire weight which may ever be on such floor will act on the wall beams and girders by a crushing force, which is the most favourable, and perfectly free from any lateral action, so long as the tension bars or plates exist.

There is another great advantage in this construction; the bays or spaces between the walls or girders may be

FIG.1.

FIG.2.

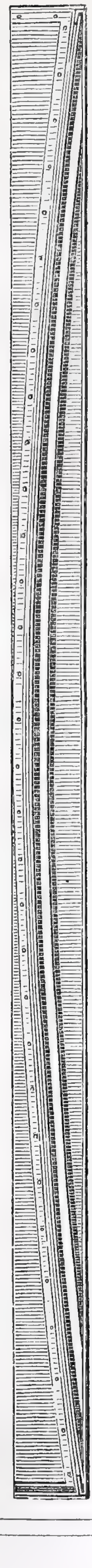


FIG.3.

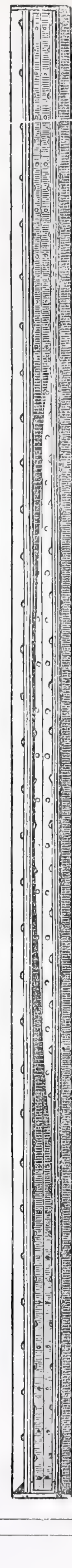
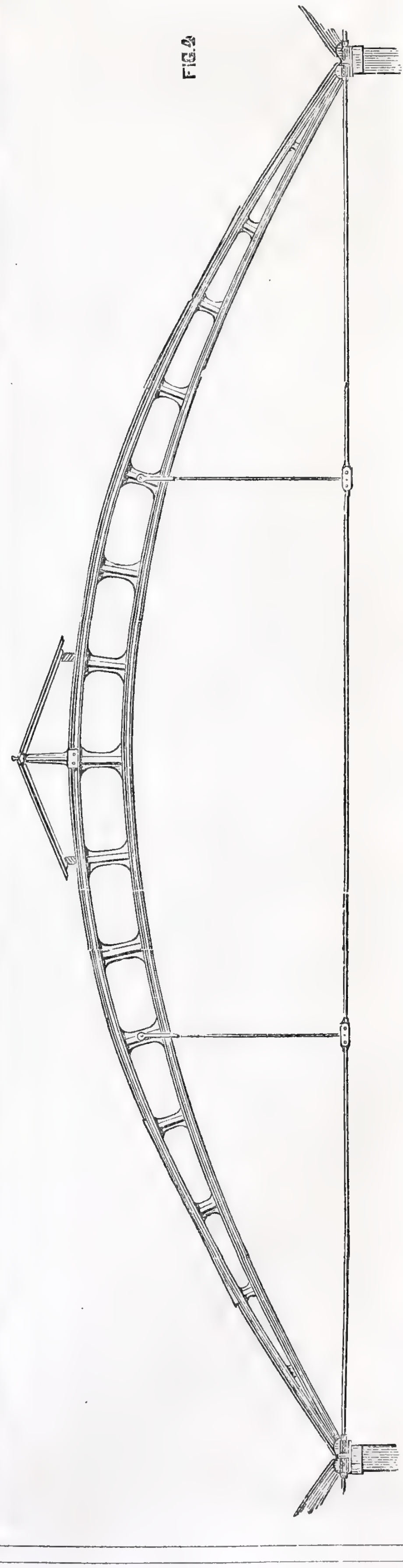


FIG.4.



wider than when brick arches are used, and of less thickness; and further, if from any unforeseen cause one or more of the plates of the flooring were to give way, no other damage would take place to any other part of the floor; each plate being quite independent, and in no other way bound to either walls or girders.

2.—AS APPLIED TO GIRDERS.

Girders, in the first place, may be considered simply as a bow and string of the required lengths; on the bow, a second arch provided with plates, and exactly corresponding with the outside of the bow, is placed. This forms a complete case over the bow, and when the girder is weighted, the arch being restrained from flattening or altering its shape by the case, the entire weight comes as a direct strain on the tension bar or string. There is no fixture or attachment to the tension bar, except at the ends, and the internal bow or strain is perfectly free from the case, as shown in the section of a girder at fig. 2, of which fig. 3 is a plan view.

Supposing a weight were suspended from the string of a bow, the effect would be to raise the crown of the bow; whereas, if the same weight were applied to a case covering the bow, the effect would be to spread the strain in the most uniform manner all over the bow, and transmit the whole weight into the chord or tension bar. For example, if a girder 20 feet long had 20 tons placed on the centre, on this principle each foot of the girder would bear one ton, and the tension bar would have to sustain 20 tons. In bridges, as at present constructed, it is customary to connect the arch to the string, in such a manner that there must be a tendency to deflect between every connecting plate. The same effect is produced where the girders are formed by applying the pressure over the top of the arch,—there is no uniform pressure or tension; whereas, on this principle, the weight can either be placed on the arch or suspended; and, in every case, if the load be placed in any varying position, the pressure and tension will be uniform. The rise of the arch from the chord has hitherto been made equal to one inch to the foot in length, and the arch constructed by placing plates of cast or wrought-iron between angle-iron; but there are other methods, as circumstances may require.

When the string or tension bars are too long for one plate, it is proposed to use a series of links, such as are used in suspension bridges; and from the great length such chains can be formed, there does not appear to be any precise limit to the span to which the girders or bridges may be carried. The chains themselves can be used as an element of increased strength, by laying them on each side of the roadway, which, being suspended from the case covering the arch, will be found to have the effect of giving rigidity.

The roadways in bridges are formed of a series of cross girders, and between them arched plates are laid, as in floors, and then filled in with ballast, as required. For bridges on this principle, no abutments of any kind will be required, all the weight being downward.

Beams or girders can be constructed of very great span, as the tensional action is the same; and to prevent the tendency to sag in the tension bars, light supports are easily placed under them, attached to the bow or case, as most convenient.

For warehouses or large rooms, where a clear space may be of consequence, the advantage of this construction will be felt in a striking manner, there being no outward thrust upon the walls, which may consequently be built thinner than usual; and there is no necessity for stay bolts.

Girders can be made to sustain any given weight, quite independent of the span, and with a peculiar advantage; viz., if a girder was made to sustain 20 tons, the same girder can be made to sustain 40 tons without making it one inch deeper; for, to attain this object, it is only necessary to increase the width of the case, and insert one or two additional arches and tension bars, as may be required,—thus only making the girder wider, which, in buildings, is often of great importance.

3.—AS APPLIED TO ROOFS.

When the patent construction is applied to roofing, the extreme lightness will be the chief feature. The bow and tension bar form the principal, and plate-iron, timber, or any other suitable material, is employed for covering the saddle or arch case. A roof upon this principle is shown at fig. 4.

4.—AS APPLIED TO BRIDGES.

This invention is peculiarly adapted for bridges, as previously stated; but there are many advantages not mentioned, one or two of which may be alluded to. When the foundations on which the pier of a bridge rest are bad, the freedom from lateral pressure is of great importance; as also in viaducts, where simple pillars or piers are built. In bridges of wide span, the outside girder can be made of sufficient depth, by making the arch of the girder and case serve for the parapet.

5.—DOCK GATES AND CAISSONS.

The principle is applicable to the construction of dock gates and caissons, particularly such as are of large dimensions. In such constructions the tension bar may be in the centre, with an arch and case on each side, capable of resisting equally the weight of water on either side.

6.—JETTIES OR PIERS.

Jetties or piers may be advantageously constructed on this principle, and may be made to extend a considerable distance at a comparatively small cost. For instance, a foot bridge or pier may be constructed to rest on the land in the usual way, on the one end, and on a barge at the other, rising and falling with the water.

In conclusion, it may be observed, the advantages attained by this invention are, that in *fireproof buildings* the walls are free from lateral thrust; the floors may be made thinner, and the number of stories be safely increased; rooms of a large size may be constructed without any pillars or supports, except the outer walls, at a much less cost than in the ordinary construction. Floors on this construction are fireproof, are easily made to sustain any given weight, or to support an increased weight, and are not liable to be destroyed by decay or vermin; and no part of the floor, by giving way, will cause an extra strain on the other parts, as the whole floor is formed of self-contained and independent parts.

In *girders*, by the combination of wrought-iron, cast-iron, and steel, their strength, form, or weight may be adapted to meet almost all circumstances; and larger spans in *bridges*, &c., can be adopted with a much less consumption of materials than in other constructions,—besides taking into consideration the slight support required from the absence of lateral thrust.

From experiments which have been made, it has been ascertained that the comparative strength of these girders, when compared with cast-iorn, is as 7 to 28, or four times as strong; that is, a girder that would weigh four tons in cast-iron, to carry a certain weight, can be constructed to carry the same weight on this principle, and will only weigh one ton.

ENGINEERING IN SWEDEN.

Amongst the natural and artificial wonders which the kingdom of Sweden presents to attract the curiosity of the modern tourist, none are more worthy of attention than her numerous mines. The vast consequence which they possess in relation to the manufactures of this country, as well as the grandeur of the scenes they unfold, combine to render them subjects of great interest. The copper mines of Tahlun, and the iron mines of Pehrsberg and Dannemora in particular, both on account of the vastness of their proportions, and the importance of their produce, are entitled to the first notice of the traveller. The terrific lateral yawn, and the visible but intricate profundity of their open workings, cannot fail to strike every beholder with astonishment, while the national industry and wealth to which they give rise, and of which they are the principal source, give them a consequence well calculated to make them frequent objects of research and inquiry, both to the native and the foreigner. Tahlun, especially, has an additional and professional importance attached to it, on account of its being the seat of the "Bergs Skola," or mineral academy,

the professors of which constitute the "Bergs Collegium," a crops of government officers, to whom is intrusted the regulation of all operations connected with mining, and whose authority respecting all processes which relate to the production of metals is paramount. To this institution Bergman, Scheele, Berzelius, and many other names of note, were considerably indebted, and under its fostering care many a humble genius has risen to rank and competence. The town, in spite of its desolate and forbidding aspect, contains permanently a great number of chemical and engineering students, and is periodically enlivened by the presence of many visitors, attracted by curiosity or the desire of information. The mines of Tahlun have been frequently and minutely described, and amongst others by Dr. Clarke, whose accurate and lucid description of the scenery, and scientific survey of the productions of the district, are well worthy of the reader's attention. The same indefatigable traveller has also devoted much of his space to the iron mines of Pehrsberg, but as these, with the same characteristics, are much inferior to those of Dannemora in extent, as well as in the richness and commercial value of their produce, it seems a pity that his attention was not more particularly directed to the latter, which would have furnished ample materials for his powerful pen. As the mines of Dannemora, therefore, though less known through the means of published description, hold the first rank in Sweden in extent and national importance, and as they affect the mechanical arts at home, perhaps in a greater degree than any other foreign mines, some short account of a visit made in the winter of 1848 may not be uninteresting to the mechanical reader.

To deviate, however, from this subject in some degree, we shall give a rapid preliminary glance at some of the processes and results of human industry which the writer has witnessed in Sweden.

By far the most important feature of the country, in an engineering point of view, is that of its internal navigation. Railway mania has not yet penetrated to that northern region; the locomotive has never yet ploughed her winter snows. From the number and extent, however, of her internal lakes, and from the enterprise and boldness with which they have been connected with one another, she possesses means of communication through an immense and most productive tract, which are of the most vital consequence to her commerce, and, indeed (if I may judge from the market price of certain canal companies' shares), seem to be amply sufficient for the present amount of her traffic. This system of internal navigation stretches completely across the country, in a north-easterly direction, from Gothenburg to Stockholm. It connects the Cattegat with the Wenern, the Wenern with the Wettern, and the Wettern with the Mälarn and the Baltic. It ramifies laterally some hundred miles, and rises and falls in its level upwards of three hundred feet.

In the completion of this work many and great difficulties had to be contended with, and high credit is due to the enterprise and talent which carried it out, more especially when it is considered that the various canals and locks have been constructed of a magnitude sufficient to accommodate sailing vessels of upwards of 50 tons burthen, and steamers of 90 feet deck and 15 feet beam.

The most difficult task, however, to perform, and one which baffled many attempts, was to surmount the abrupt ascent of 120 feet, at the celebrated falls of Trollhättan, situated on the river Götha, about thirty miles above Gothenburg, and twenty below the Wenern. Of these attempts the most notable was that of Polhelm, a native engineer of the last century, known by many skilfully executed hydraulic works at Carlskrona and other places. This man, although he appears to have chosen a most difficult site for his operations, had the daring to commence the construction of a sluice of 60 feet lift, to which it was his intention to adapt vertically sliding gates. The whole was cut out of solid granite, and a tunnel driven for the conduction of the boats to the foot of the falls, after their subsidence to the lower level. This work, however, owing to the expense of reconstructing a dam, which was carried, during a flood, over the falls, and to many other unforeseen obstructions, was interrupted and ultimately relinquished. Its remains may be seen at the present day about midway up, and at the very margin of the falls, attracting the attention of the stranger as a monument of unrequited labour. A stray stream, of no mean dimensions, separated from the vast mass of waters, falls over its verge, and rolling through a dark and uneven bed, mingles again with its parent river. The entrance to the tunnel may be seen, overgrown with brushwood, at the foot of the falls, about a quarter of a mile below. The problem of passing these falls, and completing the navigation between the Wenern and the sea, was solved by our countryman Telford, by cutting a canal of some extent, and by a circuitous route, so as to take advantage of ground better adapted for the means of overcoming the descent. Here he constructed a series of locks, which, however, have been for some years superseded by the larger and more modern structures of Colonel Ericsson,* the talented brother of John Ericsson, so well known in this country as a mechanical engineer. These latter, rising as they do in rapid succession up the steep declivity of a hill, present altogether a most remarkable and unwonted sight; and the traveller is invariably astonished and amused, on entering the first lock by a sudden turn, to behold the mast of a vessel or the funnel of a steamer buried midway in the hill, or appearing gradually in sight a hundred feet above. The number of locks is ten, to pass through the whole of which occupies a period of two hours.

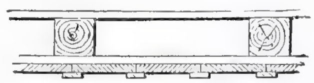
The science of architecture has never risen to a very high grade in Sweden, although this fact seems to be due, not to any want of talent in the constructive arts, but solely to the scarcity of suitable, and the intractability of their common building materials. Granite for the foundations, and brick or wood for superstructure, are those which are of universal adoption, and which are almost all that the country affords.† Sandstone is extremely scarce, and of an excellence of quality nowhere found, while whatever lime is used is procured from Gottland. The buildings which have the greatest architectural pretensions, are the two cathedral churches of the universities of Lund and Upsala, and the royal palace at Stockholm. The two former, although of vast proportions, are not to be compared, in richness or design, either to our own or to other continental structures of the same class, and are mainly remarkable for the historical wealth which they possess. The latter, however, which was built by Tessin in the last century, well merits the admiration with which travellers usually speak of it. It is true, that the interior possesses few architectural attractions, and the exterior is to a great extent plaster; but, owing to its wonderfully commanding situation, and the genius which took advantage of whatever means and appliances were within his reach, it is altogether a work of which the nation may be justly proud. The Riddacholms Kyrker, in Stockholm, although in the main a building of plain character, is worthy of notice, as having a perforated cast-iron spire of great beauty, and requires only to be better known to be taken as a precedent. Cast-iron has also been liberally employed in a handsome Exchange lately erected at Gothenburg; but, owing to its having

* This gentleman, at the time of the writer's visit, was erecting, besides various public works in Finland, a ship's sluice in Stockholm, between the Mälarn and the Baltic, on such a scale, and in so sound a manner, as does credit to the skill of the engineer, and the enterprise of a country whose revenue is by no means rich.

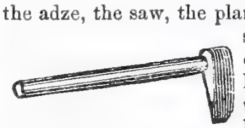
† Porphyry of superior quality is found in Dalarne, and is wrought with great skill by an apparently rude race of people. Two magnificent vases of this material, in the Djurgarden at Stockholm, and belonging to the king, have been coveted by all nations. In sculpture, indeed, of a higher order, although not in painting, the Swedes have particularly excelled: their capital possesses many noble memorials of their genius, while the name of Togelberg holds no mean rank amongst living artists.

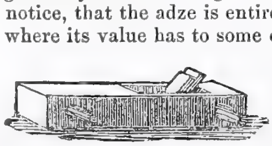
been injudiciously used solely for the purpose of external ornamentation, to the exclusion of its more valuable property of strength, the building is much open to criticism.

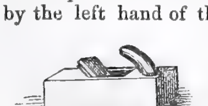
As wood is a most abundant material in Sweden, cheap, and easy to be procured, so wooden architecture is the most universal. The woods chiefly employed, as adapted to their various purposes, are the two pines—*pinus abies* and *pinus sylvestris*, of which, intermixed, unlimited forests exist—the white birch and the beech, which, in the south, is found in abundance. In the mode of constructing houses of wood there is scarcely any variety, and the same methods are now in use which existed centuries ago. They are, in consequence of long habit, built rapidly, a few days generally sufficing for their erection, and at a very small cost. A foundation or plinth of rough granite is first laid to a height of about two feet above the ground, on which are bedded longitudinal timbers containing mortice-holes for the uprights; these, which are from 5 to 8 inches square, are again tied together by horizontal pieces and diagonals, at intervals suited to the position of the doors and windows: the whole thus constitutes a frame, to which the boarding is nailed. The inner lining is generally single, of $\frac{3}{4}$-inch deal, the outer being double, of planks of the same dimensions crossing one another at right angles, while the exposed joints, which run perpendicularly, are again covered with a thin slip. The space between the outer and inner lining is usually filled in with shavings, moss, or other non-conducting material; the outside is painted a dirty red, and is surmounted with a peaked roof of red tiles. Partition walls are made in a similar manner, as also the floorings, the lowest of which is invariably double, and well filled in with the materials before mentioned. Houses thus constructed, and warmed with earthenware stoves, similar to those of Russia, are impervious to the severest winter. The most terrible enemy they have to encounter is fire, it being no unfrequent occurrence for a whole town to be swept to the ground in one night: this has happened within the writer's knowledge.



The tools employed by the joiner and builder (*timmerman*) are of the most simple kind, and are frequently handled with a considerable degree of rude skill. A few remarks on their form and use may be here submitted. The axe appears to be the favourite implement in the hands of the artisan, and is his constant companion, being used for a variety of purposes, which would, perhaps, excite the ridicule of the English carpenter: it fells the tree, it squares the log, it shaves the plank, it cuts the mortice and the tenon; it is used in skilled hands in lieu of the adze, the saw, the plane, the chisel, and the hammer. Its shape is shown in the accompanying drawing, being much more wedge-like, heavier, and apparently clumsier than its English counterpart: it is, however, better adapted to its purpose than its first appearance would lead us to suppose, and is generally used with a great deal of precision. It is worthy of notice, that the adze is entirely unknown, except in shipyards, where its value has to some extent become appreciated. The plane used by the "timmerman" is extremely rude and unwieldy, having a single plain iron and four handles, so as to be worked by two men facing each other, the one pushing and the other drawing. The smoothing plane has a species of horn at one end, which, in use, is firmly held by the left hand of the workman, though in what manner it assists him it is hard to conceive. A similar curiosity attaches to the hand hammer in common use, namely, in its having one of its nail-extracting prongs prolonged to an unusual length. The use of this appendage, the uninitiated would find it difficult to guess, and would probably solve the mystery by the supposition that both prongs had formerly been the same length, and that one had been broken off short. This, however, is not the case, the fact being, that this projection is made to discharge the office of a gimlet. It is struck with some dexterity into the timber at the part fixed upon for the insertion of the nail, the point being rounded off, so as to crush the fibre of the wood without splitting it.







The hand-frame saw employed by the Swedes being similar to that used in England for cutting curved work, it is unnecessary to describe. The pit or large frame-saw seldom comes into requisition, as a saw-mill may be seen on almost every stream. These are the most simple and primitive machines which it is possible to conceive. They consist merely of a vertical spindle, with a horizontal wheel with vanes at the bottom, and a crown wheel driving a trundle (all of wood) at the top: the trundle is fixed on a horizontal cranked shaft, which works the frame. This contains generally but one blade, which is of wrought-iron, and not unfrequently a quarter of an inch thick. This rude apparatus is erected "any how" on any convenient stream, the main requisite being attended to, viz., that the water is directed in such a manner that the vanes may catch its impulse. Over all is erected a rude kind of shed. Millstones are, for the most part, driven in the same manner, but may often be seen worked directly by the vertical spindle, without the intervention of any toothed gear whatever.

The hamlet of Dannemora lies about 120 miles north from Stockholm, somewhat eastward of the direct northern route, and about midway between the two small but important towns of Upsala and Gefle. On approaching the locality, the signs of its mineral wealth are visible in the gradual thinning of the forest by the charcoal-burner, in the mounds of scoria, and in the numerous quarries, overgrown with a thin and stunted vegetation, marking the sites of mines worked and exhausted, perhaps, ages ago. When we consider that the ore of this district is the richest that Sweden produces, is easy of production, and, before it has in a great measure become exhausted, has lain, for the most part, near the surface—we cannot be surprised that here has been the scene of some of the earliest efforts of mankind to convert the mineral treasures of the earth to their use. That such, moreover, is the case, we may gather from the fact, which seems to have been ascertained to the satisfaction of antiquarians, that the so-called "Stora Grufwan," or Big Mine, was worked before the Christian era. Whatever doubt, however, may be attached to this statement, that the commencement of this mine dates from very remote antiquity, is fully proved from its great magnitude, combined with our certain knowledge, that at no period known in its history have the operations carried on therein been very extensive, while for many centuries they have been suspended altogether. At the present day, when the spot is in full activity, a great number of mines and quarries are worked, the principal of these being the one just alluded to, and the "Jungfru Skackt," or Maiden's Shaft. This last is the deepest, but vastly inferior to the former in point of lateral size and grandeur. No working of the district, indeed, exceeds a depth of 700 feet; but the terrors of the "Stora Grufwan," which are open to full daylight at a depth little short of 500 feet, cannot fail to leave a lasting impression on the mind of every stranger who beholds them.

Travelling southwards from Gefle, during the winter of 1848, the writer, with a few companions, determined upon making a detour for the purpose of visiting this celebrated mine. Arriving, accordingly, on the morning of the second day, we dismounted from our sledges, and dismissing them to the neighbouring village of Osterby, bent our steps up a gentle ascent, formed by the mine refuse which centuries had accumulated. Here we were greeted by sounds of subterranean thunder—loud, prolonged, and reverberating. It was the appointed hour, 12 o'clock, when the miners leave their work, in order that all the blasts prepared during the last twenty-four hours may be discharged at once, and without risk to any one, except the "blast master," who alone remains below. Of this performance we were too late to be eye-witnesses, although the sound thereof was truly terrific, and we obtained our first view of the shaft when the last wreaths of smoke were rising slowly up the vast yawning gulf. Determined as we had previously been, in spite of the

many glowing descriptions which had been given us, to be disappointed with everything we saw or met with, it was with a double amount of astonishment we now beheld the scene before us—an astonishment amounting to awe, which it is impossible to describe. Suffice it to say, that within a few paces lay a yawning abyss, whose jaws were cleft asunder to so enormous a width, that the lowest depths were distinctly visible to the eye; the verge abrupt and precipitous, while the sides and bottom, being bored and reticulated in all directions, looked, in the distance, jagged and uneven, and might be compared to nothing so aptly as a gigantic fracture of pumice-stone. Attached to the face of the rock, in all possible and apparently impossible positions, were numerous ladders, serving for the purpose of ascent and descent—perpendicular, slanting, leaning, and overhanging in a manner which suggested anything but the idea of security. At uneven intervals round the verge were also ranged a number of scaffoldings, projecting fearfully over the gulf, each covered with a pent roof, and containing a horse gin, a large drum, and two pulleys, from whence depended the ropes and buckets employed in raising the ore, looking, midway down, like thimbles suspended by cobwebs. This mode of ascent and descent is also much used by the miners, and, as it precludes the necessity of exertion, is preferred. The ropes are formed of iron wire intermixed with hemp strands, and are not more than 1¼ inch in diameter: as they are manufactured, however, on the spot, with great care, of the best materials, and are changed immediately on symptoms of decay appearing, they are seldom known to break. Our guide, who had worked thirty years at the mine, informed us that he had never known a life to be lost through the breakage of a rope, nor through the falling of a ladder. The latter, indeed, on closer examination, appeared more secure than we had at first supposed, being strong, broad, and firmly bolted to the rock. Although, at the time of our visit, they were all more or less coated with snow and ice, we were informed by the same authority that accidents caused by the feet slipping were extremely rare—the greatest number being due to the falling of stones, loosened by ice or other causes. Icicles, also, are frequently a source of danger, growing, as they do sometimes, to an enormous bulk and length. And now commenced the busy scene of the after-dinner descent of the miners. Clothed in coarse woollen dresses, with thick woollen mittens to protect their hands, and heavy outside boots—the soles thickly studded with spikes—they distributed themselves to the different ladders and buckets, and addressed themselves to their dangerous downward journey with a coolness and deliberation that somewhat surprised us. Conversing rapidly to one another in their descent, their words gradually became to us inarticulate shouts, repeated in a thousand reverberations, while their bodies became foreshortened till little could be distinguished, save the broad brims of their peaked hats. Having thus followed them with our eyes—each to his respective station—and having watched their operations for some time with great interest, we addressed ourselves to the task of screwing up our courage to the requisite point for making a descent. On communicating our desire, however, to the guide, we were informed that, in consequence of some late accidents from falling stones, strangers were not allowed to descend the large mine: permission, however, would be granted to explore the "Jungfru Skackt," to which we accordingly proceeded. This mine having a narrow opening, diminished, moreover, by being partially boarded over, widens out gradually downwards, and assumes a form very much resembling a bottle. After due deliberation, and inspection of the rude hoisting machinery, and after sundry grave doubts as to whether the rope was sufficiently strong to hold the combined weight of four individuals, we stepped boldly into the bucket, and were swung over the small dark aperture; a torch was placed in each of our hands, the horse went round, and down we went. Swinging from side to side, we were protected from striking against the rock by the foot of our guide, who stood on the edge of the bucket for that purpose, till, after some yards' descent, we emerged into an immense dome-shaped cavern, whose sides could be dimly descried by the torch-light—black and rugged, and traversed here and there by ladders and pump-work. Looking downwards, all was utter darkness, except where a small fire glimmered, and revealed the solitary figure of a miner attendant thereon; while upwards nothing was seen, save the slender thread by which we were suspended, pointing to a small speck of sky. In strong contrast with the murky void surrounding us, was the red glare of the torches on our small group—a contrast which impressed us fearfully with the isolated nature of our temporary situation. This we had, certainly, sufficient time to contemplate, as our descent was anything but rapid; and when we at last touched the bottom, it was with feelings of great relief that we released ourselves from our narrow confinement, and commenced our further explorations on foot. Here the man attendant on the fire saluted us with a bow that might have become a Parisian, and bade us beware of a hole in the floor of the mine, of narrow dimensions, but of depth sufficient to justify the warning. Approaching cautiously, we saw that it was the entrance to a second bottle-shaped cavity of about 100 feet. At the bottom could be distinguished lights and figures moving about in many directions; while the sound of human voices, mingled with that of many hammers, rose magnified and confused, as if through the cavity of an immense ear-trumpet. This working, as it is entirely modern, and being a counterpart, on a diminutive scale, of the one immediately above, we omitted to explore, in order to give the little time at our disposal to the long galleries and lofty excavations which branch from the principal floor of the mine, and from which has sprung the former wealth of this mineral honeycomb. Each of these adits has its history, and with most of them are connected stories of interest, while they usually bear the name of some king or prince who in times gone by has visited them. The present king, Oscar, and the crown prince of Sweden have both been here, and left their names inscribed on the granite rock. The aspect of these desolate regions is cold, black, and cheerless, and one part of the mine differs little from another, save in the dimensions of its wide chambers, and in the height of its vaulted ceiling. Having thus traversed many hundred yards of subterranean corridor, crossed several ravines and water pits, and ascended and descended many ladders, the lateness of the hour and the waning state of our torches warned us to retrace our steps, which we did with feelings of deep interest in the steady perseverance that had slowly accomplished so mighty results.

The water of these mines, during some seasons, is raised by steam power, but owing to the very small quantity which accumulates, it is seldom that the engines are required to be in work, the daily work of a few horses being found sufficient. The pump gear is of the rudest construction, the barrel being generally of cast-iron, and the trunks timber, either constructed by nailing planks longitudinally together in the form of a square, and jointing them end to end, or by boring out the entire trunks of pine trees with a long auger, and connecting them together. The usual method of connecting the pump rods with the driving power is very simple, and so numerous are these machines, that a lengthened row of vibrating levers may be seen in some parts of the country, where water power is found in the neighbourhood of mines, stretching sometimes over smooth or uneven ground to a length of upwards of a mile. The pump bucket is one frequently employed in Sweden for many purposes, and although rude in construction, it is extremely simple, and will be found to answer its purpose effectively on an emergency. It consists merely of a square piece of leather gathered up at the four corners, and connected with the rod by means of four short chains, the rod also having its bottom firmly attached to the centre of the leather. It will be seen that a bag is thus formed, which collapses at the down-stroke, allowing the water to pass, while it distends again at the up-stroke by the weight of water it carries up, and thus keeps itself perfectly tight. The barrel in this case is square, and built of planks, as before explained.

It is much to be desired that the mines of Sweden should be explored and minutely described by some thoroughly scientific person. We have no doubt that a well qualified engineer might introduce great improvements in the mechanical working, and that, by a little outlay on such improvements, the mines might be rendered much more remunerative to the government.

COMPENDIUM OF LOGIC.

CHAPTER VIII.

PART IV. OF FALLACIES CONTINUED—SEMI-LOGICAL AND NON-LOGICAL FALLACIES.

We have stated that Fallacies or Sophisms are naturally divided into three classes; 1, Logical Fallacies, or those in which the unsoundness of the argument appears from the mere form of expression, without regard to the meaning of the terms; 2, Semi-logical; and, 3, Non-logical, or Material Fallacies. In last chapter we enumerated the fallacies of the first class, and now proceed to an examination of those of the second and third.

II. SEMI-LOGICAL FALLACIES, OR THOSE OF AMBIGUOUS MIDDLE.

Semi-logical fallacies include all the cases of ambiguous middle term, except its non-distribution. When the middle term is not distributed, the two extremes are compared with *two parts* of the same term, which may, or may not happen to be different parts; but in the case of fallacies arising from ambiguous middle, the extremes are compared with two *entirely different* terms, expressed by the same, or by similar words, used in two different senses in the two premisses. In both cases the conclusion *does not follow* from the premisses; but in the case of undistributed middle, this can be shown from the mere *form* of the expression, even supposing the terms to have no understood meaning (as A, B, C), while, in the case of ambiguous middle, the fallacy can only be detected by a knowledge of the meaning of the term, combined with some knowledge of the subject. Logic, in this case, only teaches where to look for the fallacy, and, hence, such fallacies are termed semi-logical.

The fallacies that fall under this head of Ambiguous Middle, may be divided into two classes, those of intrinsic and those of incidental ambiguity. In some cases, the middle term has *in itself* two significations, or is *intrinsically ambiguous;* in other cases, it is merely ambiguous from the context, or from what is understood in connection with it, and then it is *incidentally ambiguous*. An accurate line of distinction cannot always be drawn between the two cases, but we shall adopt the division as the best that can be made in the circumstances.

I. Intrinsic Ambiguity of the Middle Term.—It is justly remarked by Whately, that "when we mean to charge any argument with the fault of *equivocal* [or *ambiguous*] middle, it is not enough to say that the middle term is a word or phrase which *admits* of more than one meaning (for there are few that do not); but we must show, that in order for each premiss to be admitted, the term in question must be understood in one sense (pointing out *what* that sense is) in one of the premisses, and in another sense in the other." Keeping this useful caution in view, the following cases of *intrinsic ambiguity* may be enumerated:—

1. *Fallacy of Accidental Equivocation.*—A term is said to be ambiguous or equivocal *by accident*, when there is no perceptible connection between its different meanings; as *light* opposed to *darkness*, and *light* contrary to *heavy; file* a mechanical tool, and a *file* of newspapers or soldiers; *Cam*, the name of a river, and *cam*, an eccentric wheel; *lake*, a colour and a body of water, &c. Fallacies resting on the double meaning of such *accidentally equivocal* terms, are generally so easy of detection that nobody could think of using them, except by way of punning or jesting, as,

> *Light* is contrary to darkness;
> Feathers are *light;*
> Therefore, feathers are contrary to darkness.

A fallacy so obvious is mere trifling. Indeed, as was formerly remarked in treating of equivocal terms, the words which admit of such accidental equivocation, are nothing but different words accidentally spelt and pronounced in the same manner—differing not less completely when used in their different senses than such words as *hare* and *hair; one* and *won; done* and *dun; great* and *grate; main* and *mane*, &c.; words which happen to be spelt differently, though pronounced the same. These words, therefore, when *merely spoken*, serve as well as the former for that amusing kind of fallacy termed indifferently a verbal jest, a pun, or play upon words. Such accidental equivocations are seldom attended with danger in serious argument. Being, as we have stated, different words, they simply correspond to the fallacy of "more than three terms."

2. *Fallacy of First and Second Intention.*—In what are called equivocal terms, however, there is generally some connection between the different meanings. These have been divided by logicians into first and second intention, according as a word is used in its general sense, or used in a restricted sense in some particular art, science, or system. Thus, every one knows the common meaning of *governor*, which, in its first intention, is applied to a ruler or master, but in its second intention, is the name of a special apparatus connected with the steam-engine. Every one knows the common meaning, or first intention, of *beast* and *bird;* but these words have generally a different and limited sense (which is their second intention), when used by the farmer and sportsman. So *horse-power*, with reference to steam-engines; *train*, with reference to railways; *grasses*, in botany, and *salts*, in chemistry, are words used in their second intention. And sometimes it happens that the second intention is more extensive than the first, as, for example, with the two words last-mentioned, namely, *grasses* and *salts*, or the word *affinity* in chemistry.

"It is evident," says Whately, "that a term may have several second intentions, according to the several systems into which it is introduced, and of which it is one of the technical terms: thus *line* signifies, in the art-military, a certain form of drawing up ships or troops; in geography, a certain division of the earth; to the fisherman, a string to catch fish, &c. &c.; all which are so many distinct second intentions, in each of which there is a certain signification of "extension in length," which constitutes the first intention, and which corresponds pretty nearly with the employment of the term in mathematics."

Fallacies founded on this kind of ambiguity can seldom mislead.

3. *Fallacy of Etymology.*—A much more dangerous fallacy is that which is based upon the practice of appealing to the etymology (or *derivation*) of words for their correct meaning. This is by no means a sure criterion. The first intention, or common meaning of a word must not be confounded with its *primary* signification, as indicated by its etymology. Frequently, the common or general acceptation differs not less from the etymological than from the second intention or technical meaning. In process of time, what was formerly the second intention of a word, becomes what logicians term the first, and then what was formerly its first intention is altogether laid aside and forgotten, except when occasionally conjured up to support a fallacious argument. A good instance of this has been given in the word *representative*, which, in its original etymological meaning, certainly signifies a person or thing exactly *representing* another; but as applied to a member of parliament (which has become its commonest use), does not by law or custom imply that the person elected to that office is not to think for himself, or to vote according to his conscience. *Pitiful, grateful* (in one of its senses), *honest* (from *honestus*, honourable, not *probus*, honest), *minister* (*minister*, a servant), *clerk* (*clericus*, a clergyman), *sophist* and *sophistry* (σοφος, wise), and many other words of modern use, would furnish fallacies without number, if metamorphosed from their present and actual meaning to their etymological import. Not etymology but usage settles the *true* meaning of words. Any appeal to the former therefore, in opposition to the latter, is generally a feeble resource to disguise or sustain a fallacy.

4. *Fallacy of Paronymous Words.*—Nearly allied to the fallacy of etymology is that of using paronymous or conjugate words, as if they were necessarily *one* in sense, because they are derived from the same root. Thus,

> *Designing* persons are dangerous;
> This man has a *design;*
> Therefore, he is a dangerous person;

Or, the admirable instance given by Whately—

> *Projectors* are unfit to be trusted;
> This man has *formed a project;*
> Therefore, he is unfit to be trusted;

a fallacy which has perhaps nipped in the bud not a few fine inventions and bold enterprises, for excellent *projects* may be formed by men who do not deserve to be classed with *projectors*, or habitual schemers. So, another good illustration—

> To be acquainted with the guilty is a *presumption* of guilt;
> Mr. A—— is so acquainted;
> Therefore, it may be *presumed* that Mr. A—— is guilty;

a case in which Mr. A—— would receive very great injustice, for to *presume* that a man is guilty, implies a belief or assumption of his guilt, not warranted by a mere *presumption*. Let it be observed that, in this case, the ambiguity is in the major, not in the middle term. We say "in the major," for "*may be presumed*" is the predicate of the conclusion, which, in strictly logical form, would stand thus, "Therefore, that Mr. A—— is guilty may be presumed."

Generally, the ambiguity is in the middle term, and hence the general name of "ambiguous middle," applied to semi-logical fallacies. These, however, as the present instance will show, may, in some cases, be the result of ambiguity in one of the extreme terms.

Art and *artful*, *faith* and *faithful*, *apprehend* and *apprehension* are similar instances which might be multiplied to almost any extent. It is often convenient to change the form of expressing the same term in different parts of the argument, and this, whether done for grammatical convenience, or agreeable variety of expression, is perfectly allowable when no alteration of sense results; thus:—

> *Robbers* deserve to be punished;
> The prisoner has committed *theft;*
> Therefore, he *ought* to be punished;

Or,

> *Benefactors* are *entitled* to gratitude;
> This man has *done me a good action;*
> Therefore, I *owe* him gratitude;

are perfectly good arguments, though not rigorously logical or syllogistic in expression. But when the words employed to stand for the same term, though paronymous, or flowing from the same source, really express a different meaning, or even a different shade of meaning; if that difference be such as to affect the conclusion, then the term in question is not only differently expressed, but it is divided into two, and there are in reality, as in appearance, four distinct terms.

5. *Fallacy of Resemblance and Analogy.*—Another source of ambiguity, and one which resembles the fallacy of first and second intention, is found in the fact that two or more things, merely connected by *resemblance* or *analogy*, have frequently the same name. Thus, we speak of the *hands* of a clock, the *mouth* of a bottle or a cavern, a *neck* of land, the *ribs* of a grate, the *leaves* of a book. These words so applied, are evidently used in a secondary sense, derived from the *resemblance* of the objects they express to those which the same words denote in their original import. In some of these cases it may be doubtful whether the sameness of name is founded on resemblance or analogy. The hands of a clock, for example, and the mouth of a bottle, do not much resemble the hands of a man or the mouth of an animal; but still there is a kind of resemblance, and also a kind of analogy between their uses. In many cases there is no resemblance; the sameness of name is founded on analogy only. Thus, we speak of *sweet* sounds, *brilliant* actions, the *foot* of a mountain, the *bosom* of the deep, because what we term a *sweet sound* bears the same relation or analogy to other sounds as a sweet taste to other tastes; brilliant actions to ordinary actions the same relation as a brilliant to a common light, and so forth. Almost all words relating to mental operations are of this analogical character—and therefore ambiguous—having been primarily applied to matter, and thence by an easy and natural process, transferred to the workings or perceptions of the mind. Thus, we *weigh* evidence; we *see* the conclusiveness of a demonstration; we *feel* the irresistible force of an argument.

Numerous are the fallacies to which analogical reasoning leads, although, as in Butler's *Analogy*, it may be legitimately used with good and useful effect. Resemblance and analogy are sometimes confounded; one thing is said to be analogous to another when there are points of resemblance between them. Analogy is, indeed, a kind of resemblance, but it is resemblance of relations, not of things. Analogy is therefore a proportion, not a similitude; and may be expressed thus—

> *The base of a mountain bears the same relation to a mountain as the feet of an animal to the animal;*

Therefore, the base of a mountain is termed analogically the *foot* of a mountain, although there is no resemblance between it and the *foot* of an animal. A sweet sound has no resemblance to a sweet taste; a brilliant action to a bright colour. These are analogical uses of the words *brilliant* and *sweet*—uses perfectly legitimate in poetry, and giving a liveliness and beauty to language, but not so well fitted for argument, except to bewilder and mislead. Thus, it is reported of a popular candidate for parliamentary honours, that when a letter was received from his rival, stating that, in consequence of ill health, he could not encounter the atmosphere of a public meeting, the former took advantage of the word *atmosphere*. "The gentleman," he said, "has informed the meeting that he cannot venture himself in such an atmosphere, but this is the very atmosphere in which I delight to breathe"—meaning, of course, by the second application of the word, a liberal political atmosphere—not the stifling material atmosphere to which his rival referred. Such fallacies as this, though generally easy of detection to a mind that is a little instructed, produce a deceptive impression on a common audience. Arguments literally worth nothing—founded on the most imperfect analogies—will often take captive multitudes on whom all the logic of the schools would be little better than lost.

6. *Fallacy of Ambiguity from connection of Time or Place, &c.*—Another source of ambiguity, which forms the groundwork of many fallacies, is the liability of different things, which are merely connected by vicinity of time or place, to be called by the same name. *Cause* and *effect*, a *whole* and its *parts*, are often confounded under one name, in consequence of this connection subsisting between them. As an instance of the former, the *heat* of the fire, and the *sensation* of *heat* which it produces in the animal frame, are seldom sufficiently distinguished except by modern chemical writers, who have introduced the word *caloric* to signify the *cause* of the sensation, as distinguished from that sensation itself. So with the word *smell*, which signifies both the odorous principle and the sensation produced by it. This ambiguity of language has led, not only to confusion and error, expressed in individual fallacies, but to entire philosophical systems of fallacy, issuing in such paradoxical assertions as that there is no heat in fire, no cold in ice, no smell in a rose, &c., since the sensations of heat, cold, and smell, could only exist in sentient beings. Nay, it is on similar principles that even the existence of matter, and of mind itself, has been denied.

In like manner, a part is often put for the whole. We speak of so many "sail of the line," so many "head of cattle," of "every soul on board perishing." A *door-way* is often termed a *door; Milton* is put for *the works of Milton; horse* for *cavalry; sacred page* for *the scriptures.* But such ambiguities are less apt to lead to serious fallacies than those that arise from confounding under the same name cause and effect.

7. *Fallacy of Interrogations.*—An argument is often commenced by putting a question, so as to procure the admission of some point of common agreement from which to start. This is the *erotetic* method of Socrates, which, however, consisted in a series of such questions, gradually leading the adversary to entrap himself. The method is fair enough when the questions are fairly put; but sometimes they are so framed as really to involve two questions instead of one; and when a direct categorical answer is demanded, the respondent cannot comply without committing himself to something which may involve a fallacy. This is termed by logicians, *fallucia plurium interrogationum.* As an example of this kind of fallacy, the following question may be put—"Do you say the law should be obeyed, Yes, or No?" If the answer is "Yes," the interrogator may proceed thus:—

> It is right to obey the law of the land;
> A. B. in obeying the law, acted contrary to his conscience;
> Therefore, it is right to act contrary to one's conscience.

If the answer should happen to be "No," of course the respondent might be charged with revolutionary principles, or might be branded as a person not fit to be reasoned with. But such interrogations are generally so framed, that if a direct answer is given at all, the interrogator knows, or shrewdly suspects *what* it will be, and has the course of his subsequent argument prepared accordingly. The truth is, that such questions do not admit of a direct categorical answer, and no prudent reasoner would be trapped into giving such an answer. The questions themselves are ambiguous, and therefore, like other ambiguous words and phrases, are not single but double. For example, the above question may either mean, "Do you say the law should be obeyed in all cases?" or, "Do you admit that the law should be obeyed in some cases?" The terms in which it is expressed will allow of either of these senses, so that it is really two questions, not one. To answer it, therefore, *directly*, if such an answer is demanded—to answer it both directly and correctly, and to fight the sophist at the same time with his own weapons, the answer itself should be double, "No and Yes." Such an answer would be quite correct—"No, in all cases; Yes, in some cases," while it would compel the interrogator to define his question.

All ambiguous words, and all kinds of verbal equivocation or mental reserve, may be rendered the bases of such ambiguous questions. Thus, "Is it ever expedient to tell a falsehood?" or, "Is honesty always the best policy?" are questions which may be conceived to require a different answer, according as the words *expedient* and *best policy* are used with reference to success in this life, or to future happiness. In such cases, the fallacious reasoner may often have two syllogisms ready, the one to be applied in case of an affirmative, the other in case of a negative answer; and both framed on the fallacious principle of having the ambiguous word in *one* of the premisses used in the sense which the respondent has admitted, without perhaps being aware that the word has another sense, in which it is insidiously used in the other premiss or the conclusion. Thus, if the respondent reply that "honesty is not always the best policy," the following line of argument may be taken:—

> Future happiness, which is the greatest good, cannot be attained without honesty;
> But you say that honesty is not always the best policy;
> Therefore, it is not always the best policy to seek the greatest good.

Or, again, if the respondent admit that "honesty is always the best policy," a not less startling inference may be drawn:—

> Honesty may lead to poverty, suffering, and ruin;
> But you assert that honesty is always the best policy;
> Therefore, the best policy may lead to suffering and ruin.

In each of these cases the ambiguous expression "*best policy*" becomes, not the middle term, but one of the extremes; in the first it is the major, in the second the minor term.

The proper method of dealing with an adversary in such cases is to insist upon an accurate definition of the terms in which he couches his question.

II. Incidental Ambiguity of the Middle Term.—The second class of semi-logical fallacies embraces those in which the middle term is not equivocal *in itself*, but incidentally ambiguous, or rendered ambiguous by the context. This class may be subdivided into three varieties:—

1. *Fallacy of Ambiguous Construction.*—This kind of fallacy, termed by logicians *fallacia amphiboliæ*, consists in the use of a sentence or proposition which may be readily understood in two senses, not from the ambiguity of any of the words employed, but from the sentence itself admitting of a double construction. The cautious responses of the ancient oracles were frequently expressed in sentences of this description, so that they admitted of a true interpretation, whether success or failure awaited the person consulting them. Thus, when Pyrrhus, desiring to assist the Tarentines against the Romans, consulted the oracle of Apollo at Delphi, he received for answer, *Credo te Æacida Romanos vincere posse* ("I believe that Pyrrhus the Romans can subdue"), a sentence not very translateable into English, but which may either mean to express a belief that Pyrrhus could subdue the Romans, or the Romans overcome Pyrrhus. A similar indefiniteness, arising from the same construction, is given by Shakspeare to one of his witch-prophecies—"The duke yet lives that Henry shall depose;" which may be interpreted to mean, either that the duke shall depose Henry, or Henry the duke. So when Crœsus consulted the oracle above mentioned, he was told that if he crossed the Halys he must destroy a great empire. This proved to be his own empire, not that of the enemy; but still the prediction, if such it may be called, was fulfilled. These ambiguities were framed by design; but sentences admitting of a double construction are sometimes written or spoken unintentionally. Sometimes, however, they are used to create (often perhaps to conceal) a dimness or confusion of ideas; and ought to be carefully excluded from writings pretending to philosophical accuracy.

2. *Fallacy of Division and Composition.*—In this kind of fallacy the middle term is used in one of the premisses *collectively*, in the other *distributively*.

The *fallacy of division* is that in which the middle term is used collectively in the major premiss, and distributively in the minor; from which it happens that, according to the common arrangement, it is taken collectively *first*, and then *divided*. Thus, "Seven is one number; five and two are seven; therefore, five and two are one number;" Or,

> All the gold brought from Australia is worth many millions;
> This piece of gold is brought from Australia;
> Therefore, it is worth many millions.

> The inhabitants of London would eat up a province in a day;
> This man is an inhabitant of London;
> Therefore, he would eat up a province in a day.

These are exaggerated cases, merely to illustrate the nature of the fallacy; but sometimes the ambiguity in question—especially a careless use of the word *all*—may lead to serious mistakes.

The *fallacy of composition* is exactly the reverse of the preceding. In this case the middle term is used *distributively* in the major, then *compounded* or used *collectively* in the minor; as, "Five and three are two numbers; five and three are eight; therefore, eight is two numbers;" or the following:—

> The inhabitants of London do not eat or drink more than those of Manchester;
> The inhabitants of London are three millions: of Manchester, three hundred thousand;
> Therefore, three millions of people do not eat or drink more than three hundred thousand.

Of course, if the absent context were supplied—"the inhabitants of London, taken individually" (in the major), "the inhabitants of London taken collectively" (in the minor)—the fallacy would appear at once, even in the most deceitful cases.

"To the same class," says Whately, "we may refer the fallacy by which men have sometimes been led to admit, or pretend to admit, the doctrine of necessity; *e.g.*, He who necessarily goes or stays (*i.e.* in realty, 'who *necessarily goes*, or who *necessarily stays*') is not a free agent; you must necessarily go or stay (*i.e.*, 'you must necessarily *take the alternative*'); therefore, you are not a free agent."

3. *Fallacy of Accidents.*—Of this kind of fallacy there are three varieties. 1. When what may be predicated of a thing simply and absolutely is assumed to be true, in *particular circumstances*, or when its *accidents* are taken into account with it. 2. When what may be affirmed of a thing under *particular circumstances*, or in connection with certain *accidents*, is assumed to be true concerning it absolutely and simply. 3. When what may be predicated of a thing in *certain circumstances*, or in connection with certain *accidents*, is assumed to be predicable of the same thing in *other* and *different circumstances*.

Of the *first* kind, the following example may be given:—

> Poisons are destructive of life;
> Cures have been effected by poisons;
> Cures have been effected by what is destructive of life.

Here, in the major premiss, the absolute or essential nature of poisons is asserted; in the minor, they are viewed in connection with the *accident* of being administered in small quantities as medicine. This is what is properly termed *fallacia accidentis*.

The *second* kind is the converse of the preceding, and is termed

by logicians "*fallacia a dicto secundum quid ad dictum simpliciter*" —the fallacy of reasoning from particular circumstances to absolute qualities—a fallacy of which the following illustration was well known in the schools:—

What is bought in the market is taken for dinner·
Raw meat is bought in the market;
Therefore, raw meat is taken for dinner;

a somewhat unpalateable inference, founded on the fact that the dressing of the meat is a little *accident* essential to the truth of the major premiss.

Of the *third* subdivision, the following example may suffice:—

A knowledge of Latin was the key to learning in the middle ages;
Learning is as useful now as it was then;
Therefore, a knowledge of Latin is not less necessary now than it was in the middle ages;

a fallacy easily confuted by adding to the major premiss, that all the works of the learned were formerly written in Latin, which (it should be stated in the minor) is no longer the case.

This *fallacy of accidents*, in one or other of the forms above stated, exercises no small influence, and leads to many unfortunate mistakes in the common affairs of life as well as in scientific researches. Valuable medicines are often condemned because of their unskilful administration in certain cases. A man who discharges with ability the duties of one office, is rashly judged to be fitted for another requiring, perhaps, very different qualifications. Things which are pronounced good in themselves often create disappointment from not attending to the *accidents* or *specialties*, which may, in certain circumstances, render them useless or worse. The quantity of food or exercise useful and invigorating to a man in health, may have very different effects on a person in a weaker condition; and this has been sometimes fatally experienced by persons who have acted on the foolish maxim (or, in other words, the gross *fallacy*) that things which are good in themselves cannot be bad in any circumstances. A good antidote to this delusion may be found in the old adage, viz., that "one man's food is another man's poison."

III. NON-LOGICAL OR MATERIAL FALLACIES.

The two great classes of fallacies to which we have hitherto directed the reader's attention, namely, the Logical and Semi-logical, are chiefly based upon defects in the *reasoning* or *inferring* process. In these the fallacy lies in the absence of sufficient connection between the premisses assumed, and the conclusion deduced, to warrant a strictly logical inference of the one from the other—the conclusion, in short, does not follow from the premisses. In Non-logical or Material Fallacies, which we are now to consider, the conclusion *does* follow from the premisses—nothing is wrong with the connecting link—but there is something objectionable either in that conclusion or in these premisses. Referring, therefore, to the *matter* of the argument—not to the form of expression—these fallacies are termed material, or, as not involving violations of the so-called logical rules, they are also termed non-logical. In fact, they ought to be termed *Logical* Fallacies—the first and second classes *Illogical*.

The old division of fallacies was into *Fallaciæ in dictione*, and *Fallaciæ extra dictionem*—fallacies in the language, and fallacies *not* in the language—a division substantially the same as Whateley's, except that, in the fallacies of language, are included both his logical and semi-logical. The fallacies *extra dictionem* correspond to the non-logical, which we shall now proceed to consider.

In these, as we have stated, the conclusion *follows* from the premisses—that is to say, the *reasoning* is correct, but there is something that renders the argument invalid, either in the nature of the premisses assumed, or in that of the conclusion deduced. The fallacies that fall under this head may, therefore, be subdivided into two classes—1. Undue Assumption of Premisses. 2. Irrelevant Conclusion.

I. UNDUE ASSUMPTION OF PREMISSES.—The first class of non-logical fallacies are those in which the premisses are such as ought not to have been assumed. These are of two kinds—1. Assuming as the cause of an effect something which is either not the cause, or not proved to be the cause: this is what is termed by logicians the fallacy of *non causa pro causâ*. 2. Assuming as one of the premisses something involved in the conclusion: this is called *petitio principii*, or begging the question.

1. *Fallacy of "non causa pro causâ."*—This fallacy consists in arguing from something which is not a sufficient cause, as if it were so. A good illustration of such an unwarranted assumption was given by Christ's disciples when they said, "Master, who did sin, this man, or his parents, that he was born blind?"—a question implying the existence at that time of a general or vulgar belief in a fallacy which might be expressed as follows:—

Any corporeal defect inherent in a man from his birth is a punishment for sin;
This man was born blind;
Therefore, either he or his parents must have sinned.

The question, as put by the disciples, is also a good illustration of the *fallacy of interrogations*, and Jesus sufficiently exposed it by answering, "Neither hath this man sinned nor his parents: but that the works of God should be made manifest in him."

A similar example of the same fallacy is furnished by an anecdote related of Charles II. and Milton, when the poet had lost his sight, after having laboured so long in the cause of the parliamentary party. "Think you not," said the monarch, "that the crime which you committed against my father must have been very great, seeing that heaven has seen fit to punish it by such a severe loss as that which you have sustained?" "Nay, Sire," Milton replied, "if my crime *on that account* may be adjudged great, how much greater must have been the criminality of your father, seeing that I have only lost my eyes, but he his head."

This fallacy is of two kinds—either the arguing from some *effect* to something which is not the *cause*, or from that which is assumed to be the *cause* to its supposed *effect*. The preceding examples are strictly of the first kind—*non causa pro causâ;* of the second is a common fallacy often confuted by experience, "So-and-so is a bad man, he cannot prosper"—meaning prosperity in this world, which too often falls to the lot of persons of indifferent character. This argument from something assumed as a cause to something which does not necessarily follow as effect, though in some degree the converse of the former, is really the assumption of a wrong cause, and, therefore, may be likewise regarded as a case of *non causa pro causâ;* for when something is improperly assumed as an *effect*, this is equivalent to assigning a wrong *cause*.

In one or other of these forms, the fallacy we are now considering prevails to a vast extent both in the affairs of life, and in the regions of scientific research. Nothing is of more common occurrence than to hear assigned by uneducated people as the cause of misfortunes or maladies, or natural phenomena, things which may have no connection whatever, except, perhaps, coincidence in time or place, with the effects attributed to them; and even in the great encyclopedia of human science, we know not how many of the causes assigned for certain effects may be erroneous, or how many present *fallacies* of this kind future researches may expose; as modern research has exploded, and even held up to ridicule, so many of the fallacies of the ancients. We now laugh at the fallacious idea that "water ascends in a pump *because* nature abhors a vacuum;" we do not believe that "earth, air, fire, and water, are the four elementary substances of which all matter is composed." We do not, as in former ages, trace the devastations of pestilence or war to the baleful influence of a comet—every extraordinary event in history to some configuration of the horoscope—every remarkable phenomenon in nature to some mysterious supernatural agency. Whole classes of causes which formerly figured in fallacies of this kind are now discarded; yet there may be many more to discard, and not a few still to be discovered as knowledge advances.

It is not the province of logic to investigate causes. This belongs to the various sciences which constitute the pioneers of knowledge. It is, however, the province of logic, when a fallacy exists, to determine *where* it exists—to point out the methods of detecting it, or guarding against its recurrence.

It is not out of place, therefore, in a logical treatise, to show that what is merely the *sign* of a thing may often be mistaken for its *cause;* or that what is really the *cause*, may often be confounded with the *reason*, and thus lead to false conclusions. These distinctions are highly important. Thus, when I say, "The weather will be fine because the barometer is rising," I speak as if the rising barometer were really the *cause* of the approaching fine weather, whereas, I can only mean by the expression that the one phenomenon is a *sign* of the other, or that the rising of the mercury is the *reason* of my knowing or anticipating that it will be fine weather. On the contrary, if I said, "It will be fine weather, for the storm is abating," or, "the clouds are clearing away," I should then be expressing the *cause*, and not a mere *sign* of the event, or, in other words, the mere *reason* of my knowing it. It is true that a cause is both a sign and the reason of that effect which is to follow. A flash of lightning is a *sign* of thunder, and gives us *reason* to expect it; it is also the proximate cause of the thunder; but *signs* and *reasons* may exist which are very different from the *cause*.

This form of the fallacy—*causa pro non causâ*, has led to mistakes in matters of the highest importance. Thus, from the abundance of money being a *sign* of wealth, it was long believed to be the *cause* of the "wealth of nations," and hence the absurd legislation to prevent the exportation of gold which formed so long the basis of our high protective duties, cramping the commerce of the country. In like manner signs or symptoms of diseases, both in the human frame and in the "body politic," are often mistaken for the diseases themselves, which lie much deeper in the system.

2. *Petitio Principii*, or *Begging the Question*.—This second form of undue assumption of premisses, consists in employing as one of the premisses, something which is really equivalent to the conclusion itself, or which at least cannot be admitted without admitting the conclusion. Thus, if a man should argue that a gallon of water must be as heavy at London as at Quito, because it is found to balance exactly the same weight of 10 lbs. at both places, he would be guilty of begging the question, by assuming as one of his premisses that 10 lbs. at London are the same as 10 lbs. at Quito; or, thus, in syllogistic form:—

> 10 lbs. at London and at Quito are the same;
> But a gallon of water weighs 10 lbs. at both;
> Therefore, a gallon of water is equally heavy at both.

Here, in the major premiss, a false proposition is assumed which really involves the false conclusion, viz., that a 10 lbs. weight, or a given quantity of matter, is equally heavy at London and at Quito—the very point to be proved.

"Begging the Question (or *Petitio Principii*)," says Whately, "has been, by some writers, imputed to every *syllogism* (*i.e.*, though they did not perceive this, to every *argument*), on the ground that the premisses imply the conclusion. And it is manifest that (as has been formerly shown) if they did *not*—if the premisses were such that they might conceiveably be *both* true, and yet the conclusion *not* true, there could be no argument at all. But the fallacy of *begging the question* takes place when the conclusion is virtually asserted (not, by the *two* premisses, which it must be in all legitimate reasoning, but) by *one* premiss—when one of the premisses either appears manifestly to be the same in sense with the conclusion, or is actually proved from it, or is such as would naturally and properly be so proved."

These remarks exactly apply to the illustration above given. To prove that a piece of iron or brass denoting a weight of 10 lbs. or 1 lb. gravitates with equal force at London and Quito, is not less difficult than to prove the same of a gallon of water. It may, however, be easier, simply as a matter of convenience (though not differing in principle), to prove the difference in weight at the two places with reference to that portion of iron which we term a pound; and if we have really performed this process, then we may reason from the 1 lb. or 10 lbs. of iron to the gallon of water.

Arguing in a circle, though generally classed as a distinct fallacy from *begging the question*, is really the same; or, if there be any difference, it bears to it the same relation as the *sorites* to the simple syllogism. A person argues in a circle when in a process of reasoning he takes for granted as one of the premisses the very thing to be proved; or, having inferred the truth of his conclusion from certain premisses assumed, then, if these premisses are called in question, he argues their truth from the conclusion as a point already established, and so moves round in a circle. Thus, a person may argue that "a piece of iron *sinks* in the sea because it is denser than water." "But how do you know it is denser?" "Because it is heavier." "And how do you know it is heavier?" "Because when immersed in the sea it displaces an equal quantity of water, and still has a tendency downward." "But how do you know it has such a tendency?" "Because it *sinks*"—which completes the circle. What is this but the reply of the physician in the French play to the person who asked why opium produces sleep?—"Because," replied the learned gentleman, "it has a soporific tendency." This is simply a begging of the question, and the process of arguing in a circle is in principle exactly the same.

Whately justly remarks that "the English language is perhaps the more suitable for the fallacy of *petitio principii*, from its being formed from two distinct languages, and thus abounding in synonymous expressions, which have no resemblance in sound, and no connection in etymology; so that a sophist may bring forward a proposition expressed in words of Saxon origin, and give as a reason for it, *the very same proposition stated in words of Norman origin; e.g.*, "To allow every man an unbounded freedom of speech must always be, on the whole, advantageous to the state; for it is highly conducive to the interests of the community that each individual should enjoy a liberty, perfectly unlimited, of expressing his sentiments"—an argument exactly equivalent to saying that opium produces sleep because it has a tendency to do so; or "man must die, because he is mortal."

Fallacies of this kind, and probably all kinds of fallacies, are much more frequently committed inadvertently than with intention to mislead. Logic is as needful for guiding our own thoughts in the channel of correct argument and sound inference, as for enabling us to guard against the fallacies promulgated by others, either undesignedly or deceitfully.

II. Irrelevant Conclusion.—The second class of Material or Non-logical fallacies are those of Irrelevant Conclusion, commonly called by logicians *Ignoratio Elenchi*,* because they consist in ignoring the *point to be proved*, and substituting some conclusion which does not settle the question, though it may have the appearance of doing so.

The fallacies of this class may be subdivided as follows—1. Shifting ground. 2. Fallacy of objections. 3. Proving too little. 4. Proving too much. 5. Suppression of the truth (*suppressio veri*). 6. *Argumenta ad hominem, ad verecundiam*, &c.

1. *Fallacy of Shifting Ground.*—Every one knows, from personal experience, that this fallacy is often resorted to by obstinate reasoners, who feel that they are *hard pressed*, and cannot maintain their position. Driven by some unexpected argument, or some undeniable fact, from the point which they began by asserting, and yet unwilling to acknowledge defeat, they take up another position, and try to make out a conclusion somewhat resembling in appearance or in principle that which they maintained at the outset. Or, sometimes, they fix upon a merely incidental expression, which, whether true or false, does not materially affect the point in dispute, and if they succeed in disproving it, they claim a triumph, or even extort from an ignorant audience the plaudits of victory, although they may have utterly failed to substantiate the conclusion required. One example of this kind of fallacy may be given. Let us suppose that the question in dispute is, "Whether the British government should, as a matter of duty, extend the benefits of education to the subjects of our Indian Empire?" On this point the parliamentary sophist, baffled or embarrassed on the question of duty, would substitute the question of prudence, and might, perhaps, argue plausibly, *on this ground*, that it would be highly *inexpedient* to educate so vast a population, at present in subjection to our sway in virtue of our higher civilization—that "knowledge is power," and that it

* *Elenchus*, argument, proof.

would be highly dangerous to arm them with such an instrument for working out their independence. He might thus succeed in proving that to educate the natives was *imprudent* or highly *inexpedient* in a selfish view—in the narrow view of national policy inspired by interested motives; but this would be a purely irrelevant conclusion—an *ignoratio elenchi;* the question of the *duty* of the government would still remain to be decided.

Allied to the fallacy of shifting ground, or one which may be reckoned as virtually the same (though generally classed by logicians as distinct), is that of *combating alternate premisses,* or *reasoning from alternate premisses to an alternative conclusion.* Thus, it is not uncommon for an adversary first to dispute one of your premisses, and then, when he finds that he cannot disprove it, to make an attack upon the other, leaving the first point still in dispute, and shifting from the one to the other without demolishing either. Such a reasoner is difficult to deal with, because he is constantly *shifting his ground,* and dragging his antagonist along with him from one position to another, until the original question is absolutely lost sight of, and nothing is gained by the discussion but some irrelevant conclusion, or no conclusion at all.

Or a sophist may be guilty of shifting his ground by arguing alternately from premisses, not with the view of *destroying,* but of *supporting* a conclusion—passing from the one to the other, without making good his point as regards the validity of either, but making out something like a case, by the mixing and blending of the two, until they appear to unite in yielding the required conclusion. Thus, if he is arguing in favour of slavery, he probably asserts, as one of his premisses, that it is sanctioned in the Bible; as another, that it *may be* expedient in certain states of society; as a third, that it *is* expedient; as a fourth, that what is really expedient, *in the proper and highest sense of the word* (thus shifting his ground), must be consistent with justice and mercy, and being at the same time sanctioned by the Bible, may be regarded as an institution at once expedient and good, and of Divine origin. Not even one of these premisses may be conclusively established; but by the rapid transition of the argument, and skilfully changing as required the meaning of the word *expedient,* a general effect will be produced on the mind, that "either slavery is really a Divine institution, or in a lower point of view it is just, or in the lowest view of all, it *is* or *may* be expedient." Here the alternative conclusion established virtually amounts to little or nothing, yet the effect produced *on the whole* may be exactly the effect which the orator wanted.

2. *Fallacy of objections.*—This fallacy consists in showing that any conclusion or theory is liable to certain objections, and thence inferring its falsity or unsoundness, without considering the arguments that might be adduced in its favour. The fallacy is based on a wilful or unconscious neglect of the maxim, *audi alteram partem* ("hear both sides"). Infidel works are generally conceived in this spirit. They urge only the objections that seem to cast doubt or discredit on the Bible, while they pass over in silence the many irresistible arguments by which its truth is supported. In this way numerous objections may be urged against almost every system of doctrine, every human institution, everything really good that exists. It is by a skilful use of this fallacy that clever pleaders will carry a jury along with them, making "the worse appear the better reason," so that the latter would often give a wrong verdict were they not previously enlightened by the speaker on the opposite side, and by the calm and impartial "summing up" of the judge. Many desirable reforms are delayed, or altogether set aside, by the opponents of such reforms, showing that numerous objections exist against the measures proposed —an argument by no means sufficient unless it can be shown that these objections are greater than those that can be urged against the existing state of things. Sometimes the champions of existing abuses will say in such cases—"We do not ask you to admit that our objections are decisive against the adoption of your measures—we acknowledge that some imperfections or abuses are connected with the present system; but seeing that objections exist on both sides, we merely require you to suspend your judgment, and not to interfere with what is established, until you can produce in its place a system free of objections." This is but another form of the fallacy, which, if it produce the delay or suspension of judgment required, results in nothing less than a triumph. A *do-nothing* conclusion in such a case, is not to compromise the point in dispute, but to give it up—to suffer the abuse to exist. The proper course would be to weigh the objections on both sides, and then, after due deliberation, to decide and act. "Non-decision," as Whately remarks, "is practically the very same thing as a *decision in favour of the existing state of things.* 'Not to resolve, is to resolve' (says Bacon). The *delay* of trial becomes equivalent to an acquittal."

3. *Fallacy of proving too little.*—Another form of irrelevant conclusion is that of proving only a part of what is affirmed, and leading the reader or hearer to suppose that the whole might be proved in the same manner, while, in reality, the part that is left to be taken for granted may be the very point that is most essential to the argument. To prove that a man is disqualified for business, it is not sufficient to show that he has failed, or become bankrupt. To prove that a general has no military genius, it is not sufficient to show that he has been compelled to retreat, or that he has even suffered an occasional defeat in battle. Yet there is no fallacy more common than to argue want of skill from want of success. Frequent failure always—sometimes a single failure—will constitute a strong presumption of want of skill; but to demonstrate the actual existence of incapacity, something more must be proved: it must be shown that adverse and unexpected circumstances did not produce the effect.

4. *Fallacy of proving too much.*—This is a species of fallacy not uncommon, and one which fortunately defeats its own object. The common objection to the syllogism is of this character. Those who urge, for example, that the syllogism is itself a fallacy—a mere *petitio principii,* or begging of the question—do not consider, that in proving, or attempting to prove, this conclusion, they are destroying their own reasoning; for every argument may be reduced to a syllogism. Therefore, if what they assert is true, all reasoning (not excepting their own) is merely a begging of the question. Their argument, therefore, proves too much—it proves itself to be a fallacy, and that is its only recommendation.

Hume's celebrated argument against miracles (namely, that they are contrary to experience, while it is not contrary to experience that the testimony on which they rest should be false), proves also too much, if it proves anything. If it proves us to be not justified in believing that miracles were performed, it proves that, supposing a miracle to have been really performed, it would be *impossible,* on rational grounds, to believe it. It proves, in short, *a priori,* that a miracle *cannot* be credited, unless actually seen with our own eyes—perhaps not even in that case, for (although "seeing is believing" yet), it is by means contrary to experience that even our eyes should deceive us. The argument, therefore, if it proves anything, evidently proves too much. If men believed nothing but what was *according* to their experience, their creed, even in scientific matters, even in natural phenomena, even in the records of history, would be very limited.

5. *The fallacy of suppressing the truth* (*suppressio veri*), is often resorted to by those who are conscious of the weakness of their cause, and feel that they can only carry their point by the studied suppression or concealment of some qualifying circumstance, which, if fairly and candidly mentioned, as it ought to be, would form an essential element in coming to a sound conclusion. Thus, it has been argued that certain government schools, or certain plans of education were "godless," on the ground that they excluded *religion;* whereas, if the truth had been fairly stated, it might have appeared that they excluded only *sectarian religion;* but then the addition of the qualifying adjective would have been incompatible with the conclusion desired. Such cases of *suppressio veri,* which are by no means uncommon in controversial writing, may be more properly referred to the assumption of false or ambiguous premisses; but a similar suppression of the truth is practised when the conclusion itself, to which the arguments lead, is never expressly mentioned, but is left to be inferred by the

audience, who, by the time that the reasoning is concluded, may have forgotten or mistaken the precise point to be proved. In such a case, each of the arguments successively may seem to be incontrovertible. They may inevitably lead to a conclusion somewhat similar in form or in substance to that which is required for the proper decision of the question; yet it may be very materially different; it may, in short, be *irrelevant;* but this the reasoner is careful to conceal by keeping it as much in the background as possible, never stating it explicitly, and only advancing into prominent notice the strong points of his argument.

6. *Fallacies of "argumentum ad hominem," ad verecundiam,* &c. These are some other forms of fallacies, known among logicians by special designations, according to the principles on which they are based, although they may be generally referred to one or other of the classes already enumerated. For example, in opposition to *argumentum ad rem* (to the *matter*), an argument addressed to the question or matter in hand, as every argument properly should be, there is the *argumentum ad hominem* (to the *man*), an argument founded on the principles, practice, or expressed belief of an antagonist—an argument quite fallacious when used as abstractedly decisive of the point at issue, although it may be used with good effect, and used also with perfect fairness, to silence an unreasonable opponent, or show forth his inconsistency. *Argumentum ad judicium* (to the *judgment*), is reasoning by appeal to common sense, which may be a fallacy or not, according to circumstances. *Argumentum ad verecundiam* (to *modesty*), is an argument which takes advantage of the modesty, obscurity, or diffidence of an opponent, by quoting some high authority which he could scarcely dispute or disregard without an appearance of presumption. Thus, we have seen a public speaker who ventured to impugn the accuracy of some parts of Hume's History, fiercely attacked by an ignorant newspaper writer for daring to set up his own researches or opinions in opposition to those of such an eminent historian; and yet it is well known that Hume, though great as a philosopher and philosophical historian, is often inaccurate in matters of fact, and not less frequently unjust in his estimate of the merits of parties. Connected with this fallacy is that of *references*, of which even Hume's History is a good example. Numerous authorities are given for the statements made; and these, if the reader will take the trouble to refer to them often represent the fact or facts in a totally different light from that which they are quoted to corroborate. This fallacy is frequently committed in controversial works of a religious nature. A long array of texts are referred to (by chapter and verse only), in support of some particular doctrine. These, from their number, appear to be conclusive, and lead the majority of readers to believe that the doctrine is beyond question; yet, if the texts are actually examined and compared, it may be that not one in the whole list, or all of them put together, really express the opinion or doctrine for which they have been referred to as *proofs*. This form of the fallacy is frequently termed *argumentum ad fidem*—an argument addressed to our natural belief in testimony.

7. *Argumentum ad populum, ad passiones,* &c., is an argument addressed to the prejudices, passions, &c., of the multitude. *Argumentum ad ignorantiam,* is one in which advantage is taken of the ignorance of an opponent, and is indeed a name that might apply to all fallacies, "being," as Whately justly remarks, "evidently nothing more than the employment of *some* kind of fallacy, in the widest sense of that word, towards such as are likely to be deceived by it." The *argumentum ad ignorantiam* is, however, to be understood as some kind of argument that could not impose on any but very ignorant persons. Such are the arguments usually employed in the *puffing* of empirical drugs and other quackeries.

8. *Argumentum ex concesso* (from something *granted* or *admitted*), is reasoning from the truth or assumed truth of a proposition on which it is agreed to give up the contested point.

It ought to be remarked, that all these different kinds of arguments are not necessarily unfair or fallacious. The *argumentum ad rem* or *ad judicium* constitutes, indeed the regular logical process, but some of the others may be used with advantage, and even with perfect fairness, in dealing with unscrupulous opponents. Whether or not their use is legitimate must be determined by circumstances. Those which imply actual fraud, as a false appeal to authorities, cannot be used with propriety or fairness under any conditions.

BLEACHING.

CHAPTER I.

THE BLEACHING OF VEGETABLE STUFFS—SCOURING MACHINES.

It is by the series of chemical and mechanical operations which constitute the art of bleaching, properly so called, that woven and textile fabrics are freed from all foreign organic or inorganic matters, whether these exist in the raw fibre in its natural state, or afterwards become incorporated with it during the processes of spinning and weaving. It is by these operations that the material is brought to a fit condition to receive the impressions of the various colours in dyeing and printing, so that such colours may combine uniformly with it, and become fixed in all their brilliancy and beauty, and that the portions intended to remain white may retain their purity even after immersion. A knowledge being obtained of all the circumstances in which the various textile fibres remain uninjured, it is necessary to select from the same circle of chemical action such agents as will directly or indirectly destroy and carry off all foreign matters.

The question being put in this form, it will at once be perceived that wool and silk, which are acted upon by alkalis, will not bear the same treatment as fabrics composed of the textile fibres of cotton, hemp, and linen (cellulose, Payen), which resist the action of these agents, as well as that of chlorine, under particular conditions; it will, therefore, be requisite to treat separately of the art of bleaching—first, as to such fabrics as have a vegetable fibre for base; second, such as are composed of animal fibres, as wool and silk, or of a mixture of both.

THE ART OF BLEACHING COTTON, HEMPEN, AND LINEN FABRICS.

The name of Berthollet has been rendered dear to the arts by his experimental labours connected with the bleaching of fabrics, which at first seemed to leave nothing to be desired; he had, indeed, so clearly defined the properties of chlorine, so well ascertained the conditions in which this colour-discharging agent should be employed, that at the time no one thought it possible to go further. Experience, however, soon began to show that this branch of chemical art was not yet established on sufficient bases; for, from time to time, various accidents occurred which it was impossible to explain, whilst some bleachers condemned the use of such and such bases, which others recommended, and it was not unusual to see those who followed these recommendations become victimized by their reliance upon them. For several years, owing to the labours of many, all uncertainty has disappeared, and at the present time the operations of bleaching are carried on upon principles both certain and easy of comprehension.

The vegetable fibre of cotton, hempen, linen, and similar fabrics, is far from pure, but has incorporated with it—

1st. A certain quantity of matter in a coloured or colourable state, which is more or less defended from the action of discharging agents by the matters naturally or accidentally combined with it.

2d. A peculiar resinous matter, naturally existing in the fibre, insoluble in water, and with difficulty soluble in alkalis, its chief action appearing to be the protection of the colourable and coloured matters inherent in the fibre, from the action of agents tending to destroy and carry them off.

3d. A certain quantity of fatty matter, a very small portion of which is inherent in the fibre, whilst the greater part is due to the spinning and weaving processes. It is known, moreover, that these fatty bodies do not always exist in the same state upon fabrics; some, modified by the air, act as mordants

—such, for example, is the grease accidentally let fall by the spinning and weaving machinery, or that intentionally introduced into the composition of the size. The others are simply the soap used to diminish the friction of the threads in the operation of spinning.

4th. A neutral substance, consisting of lies, starch, flour, or size, according as one or other of these is used in sizing the warp. It should, however, be remarked, that at present lies are not generally used, because they do not contain any gluten like flour, by which the latter is preserved from decomposition, and prevented from changing to a carbonate of ammonia—a salt which, when exposed to the air, converts the fatty bodies into an organic mordant, always insoluble upon the fabric, from which it is only with the greatest difficulty that it can be removed.

5th. Inorganic saline matters, some of which are inherent in the fibres, others derived from the water and other ingredients of the size applied to the warp. The sulphates of copper and zinc figure amongst the matters alluded to; but these salts soon disappear in consequence of the double decomposition they undergo, and the modifications experienced by their bases from the action of neutral substances, so that it would be impossible to assign them any definite order of combination.

If, now, all the above substances were abstracted, and we had to deal with a fabric consisting only of vegetable fibre and colouring matter, the problem of bleaching would be as simple as it is easy to solve; it would suffice to carry off directly, or, if this were not possible, to modify, in the first instance, so as afterwards to carry off the colouring matter which accompanies the fibre, rendering the latter free and pure with all the characteristic properties which give it value; in a word, there would be but one operation to go through, which might be termed the *decoloration of the fibre.* The presence of foreign matters, more particularly of resinous and fatty substances, greatly complicates the operation, for these substances oppose the action of agents intended to modify the colouring matter and render it soluble, so that this action cannot effectively take place unless such resinous or fatty substances have been previously caused to disappear; otherwise, the decoloration of the fibre would be incomplete and the white imperfect, or, if the operation be carried to the extreme, the quantity of the decolouring agent would be so great as to damage the fabric more or less. In consequence of this it is, that a series of operations are required previous to that of decoloration, and these we comprehend under the term *scouring of the vegetable fibre.* This scouring and decoloration are the two fundamental processes in bleaching.

The scouring of the vegetable fibre consists of two kinds of operations, chemical and mechanical. In the first, the fabric is submitted to the action—

1st. Of one or two lime lies, with the chief object of saponifying and forming calcareous combinations with the inherent fatty or resinous matters.

2d. Of a wash acidulated either with sulphuric or hydrochloric acid, to decompose the calcareous soaps formed during the preceding operation, and set free the fatty or resinous acids.

3d. Of one or more lies of carbonate of soda, to bring about the solution of the above-mentioned acids.

The second, which are complementary to the first, are for the purpose of carrying off soluble and insoluble matters, found either upon the surface or in the interstices of the fabric.

SCOURING WITH LIME LIE.

If at the beginning we had simply stated the question of bleaching, and sought for the agent most capable of saponifying the fatty matters, and of doing this advantageously, lime would inevitably have been selected for this purpose, being a base which acts *more energetically upon fatty bodies than any other;* but as, in the first applications that were made of this base, it was simply taken as an economical substitute for potash and soda, the principle of its action and the means of regulating this were not considered. Some rejected the use of it, because, said they, it burned the cloth; and in fact this was often the unfortunate consequence of its use: others reproached it with forming insoluble soaps upon the cloth, which, combining very intimately, took up the colouring matter irregularly, so as to produce stains. The question, however, completely changes its aspect when it is known in what conditions the lime may be in contact with the vegetable fibres without affecting them, and when it is stated that it forms a calcareous soap with the fatty matter it may meet with, which soap must be decomposed by an acid, and the saponified substance carried off by a lie of carbonate of soda.

To whom is due the merit of this discovery? This it is impossible for us to state precisely; he who first employed lime in a rational manner was too much benefited by his secret to divulge it; all that we can say is, that before Messrs. Dana and Prince, near Boston (a letter addressed to the *Industrial Society of Mulhouse*, vol. x. p. 281), no one had made known or explained the principle of this process. M. Guéraud, senior, of Troyes, did indeed, in 1835, publish a very interesting memoir on bleaching, in which the employment of acids is considered as indispensable for obtaining a perfect white.

According to our own observations, lime not only possesses the property of rapidly saponifying fatty matters, and of attacking resinous matters more actively than other bases; but it has also the power of contributing to the oxidation of the colouring matter of the fibre, assisting the metamorphoses it has to undergo in order to be carried off; of vigorously attacking the principle of the tissue; and, finally, of maintaining the vegetable fibre in the state of contraction of so much value in the felting process. This state of contraction, which does not seem hitherto to have met with sufficient consideration from manufacturers, is nevertheless worthy of the most serious attention; because, if a lie is caused to act upon a fabric, and, above all, a cotton one, and is too weak, it will not cause the fibre to contract, nor restrain the development of down, the presence of which upon the surface of the fabric destroys its brilliancy and beauty; if, on the other hand, the lie is too strong, the fibre will then be severely contracted, and may be injured. Thus two things are to be avoided in this operation, and this is only done by ascertaining the precise degree of concentration at which the lie will be sufficiently strong to cause the fibre to contract as much as possible without injuring it. With lime, however, which is a base possessing but little solubility, these inconveniences have not to be dreaded, nor have like precautions to be taken.

When the nature of the base proposed to be employed in bleaching is known, under what conditions should it be made to act, and what apparatus are the best for developing a beneficial action upon the fabric?

As vegetable fibres cannot exist under the combined influence of lime and air without experiencing more or less injury, it is necessary to protect them from the air as long as the lime is in contact with them. On the other hand, if one does not lose sight of the fact, that saponification takes place more rapidly under pressure, or, what is the same thing, at a higher temperature, it is easy to determine the temperature at which the operation is to be performed, and consequently to select, from the numerous apparatus proposed or used, the most advantageous one for these purposes.

SCOURING MACHINES.

Scouring machines may be classed in two fundamental divisions. In the one kind, the fabric is simply placed in contact with the lie, the temperature of which is raised, either by the direct action of a furnace or by means of steam. In the other kind, the operation is exactly like that of rinsing or draining lie, as commonly practised; the lie, heated in a separate vessel, is caused to ascend, either mechanically or physically, to the upper part of the copper, containing the goods to be bleached; it passes through them, and reaches the bottom of the copper, whence it returns to the boiler, where it is reheated, and it is again passed through the goods repeatedly, as long as the operation lasts. The apparatus in which this operation is carried on are called *circulating* scouring machines, amongst which are distinguished those in which the circulation is intermittent.

We shall explain, in the first place, the system of *direct heat*—1. by a furnace; 2. by steam.

1. The forms of the vessels employed for boiling are infinitely various; notwithstanding, as we cannot obtain all the advantages appertaining to this system of heating, unless the lie is raised to a very high temperature, it is necessary that these vessels should be of such a form and material as to resist the pressure of two or three atmospheres, without which the lie cannot be raised to a temperature higher than that of boiling water.

In 1804, M. D. Kœchlin employed a boiler of such form and dimensions, that fifty to sixty pieces were kept in it in a boiling state for four hours. In some establishments they employ a boiler of strong iron plates, of an ovoid form, in which they can boil from 1500 to 2000 mètres of calico with a sufficiency of lie. The bottom and sides of this boiler are sheathed internally with wood, to prevent the direct contact of the goods with the sides of the vessel, the very great heat of which might injure them, at least at some parts. The opening into the boiler is fitted with a circular flange, to which a cover is adjusted, and hermetically secured by bolts, or by a bridle and screw. The defect that may be attributed to this system consists in the fact, that the operations are intermittent instead of continuous, and that the economy of fuel derived from it is partly neutralized by the loss of heat and time occasioned by the necessity of waiting until the vessel is cool before taking out the goods and replacing them by others. This defect would be avoided, we think, and all the advantages retained, by employing three small moveable boilers, each capable of containing fifty pieces, together with the necessary quantity of lie, and each being adapted to a single furnace. According to our experience, it is sufficient to boil a fabric during twenty-five or thirty minutes, under a pressure of 2½ to 3 atmospheres, to bring about the complete saponification of the fatty bodies with which it is impregnated; now, a day's work being taken at twelve hours, it will be seen that, with the assistance of these three boilers, one of which will be full and with its contents boiling, another in the act of being filled, containing water previously economically heated in a vessel placed in a position to utilize the waste heat of the furnace, and the third in the act of being discharged—it will be easy to scour or submit to the action of the lime lie, 1000 to 1200 pieces per day. The only expense incurred beyond that of ordinary systems of scouring, will be the putting up of a crane to enable a couple of attendants to move and change the boilers as required. Not only will the above process occasion an economy of fuel, but half the quantity of lime usually employed will, by it, be rendered sufficient; whilst the action will be more uniform, than where large masses of goods are operated upon.

2. The apparatus heated by steam are of two kinds; in one, the boiler or steam generator is quite distinct from the copper, in the other it is in connection with it. A very few words will give an idea of these apparatus. Let a vessel be imagined, constructed of wood, or of cast-iron where it is not desired to have frequent cause for repair, capable of containing 400 to 600 pieces of 60 to 70 metres each. At the lower part is placed a perforated false bottom, in the centre of which is a tube serving as a means of communication between the top and bottom of the vessel and the steam boiler: it is on this false bottom that the pieces of goods, previously impregnated with lie, are piled up to within a certain distance of the top; these are then covered with a wooden grating, which retains them immersed at a constant level. The vessel is surmounted by a moveable cover having an opening, to which is fitted the pipe conveying the steam below the false bottom. By means of a steam boiler placed in communication with two or three vessels, A, B, C, similarly disposed, a continuous action may be maintained; for whilst the steam is allowed to enter the vessel, A, to heat its contents, the vessel, B, may be in the act of being filled, and the third, C, in the act of being discharged, or *vice versa*. When the boiler shall have produced the desired effect in the vessel, A, all communication between it and the boiler may be stopped by closing a stop-cock; and by opening another, the steam may be conveyed to the vessel, B, and afterwards to the vessel, C. By this system of boiling or scouring, several vessels may be heated by means of one boiler, which may also be made to serve other purposes besides bleaching operations: it is not, however, on the other hand, without several disadvantages: it always occasions a great expenditure of fuel when there are not many vessels to be heated, and when the excess of steam cannot be utilized by heating dye vats, or otherwise: it has also the effect of rendering the lie too dilute, for the volume of the latter is augmented by the quantity of water given out by the steam in raising the lie from the ordinary temperature to boiling heat, which is equal to not less than a sixth, as well as that due to the condensation caused by the general radiation of the heat; it is obvious, that a lie diluted in this manner must be naturally weakened, whilst this accumulation of water curtails the time of ebullition, since, as soon as the vessels become full of liquid, it is necessary to stop the operation.

In the other steam-heated scouring apparatus, the boiler is in immediate connection with, or forms part of, the vessel in which the goods to be operated upon are put. To form an idea of it, it is necessary to imagine a copper or iron-plate boiler, the bottom of which is concave externally, and convex inwardly: two or three decimetres above the actual bottom is a grated false bottom, upon which are piled the goods previously impregnated with the lie, the boiler is surmounted by a cover which closes it hermetically: the space below the false bottom is filled with water, so that, on lighting a fire below the boiler, this water is made to boil, and the steam, generated gradually, rises through the goods, and as these exert some amount of pressure, the temperature is somewhat over 1000 Centigrade.

This system of scouring has this advantage, that the alkali is in immediate contact with the fabric under the influence of a certain pressure, a circumstance which we have already pointed out as more favourable for the saponification of the fatty bodies. (See Péctet, *Treatise on Heat*, p. 283, pl. 96.)

CIRCULATING SCOURING MACHINES.

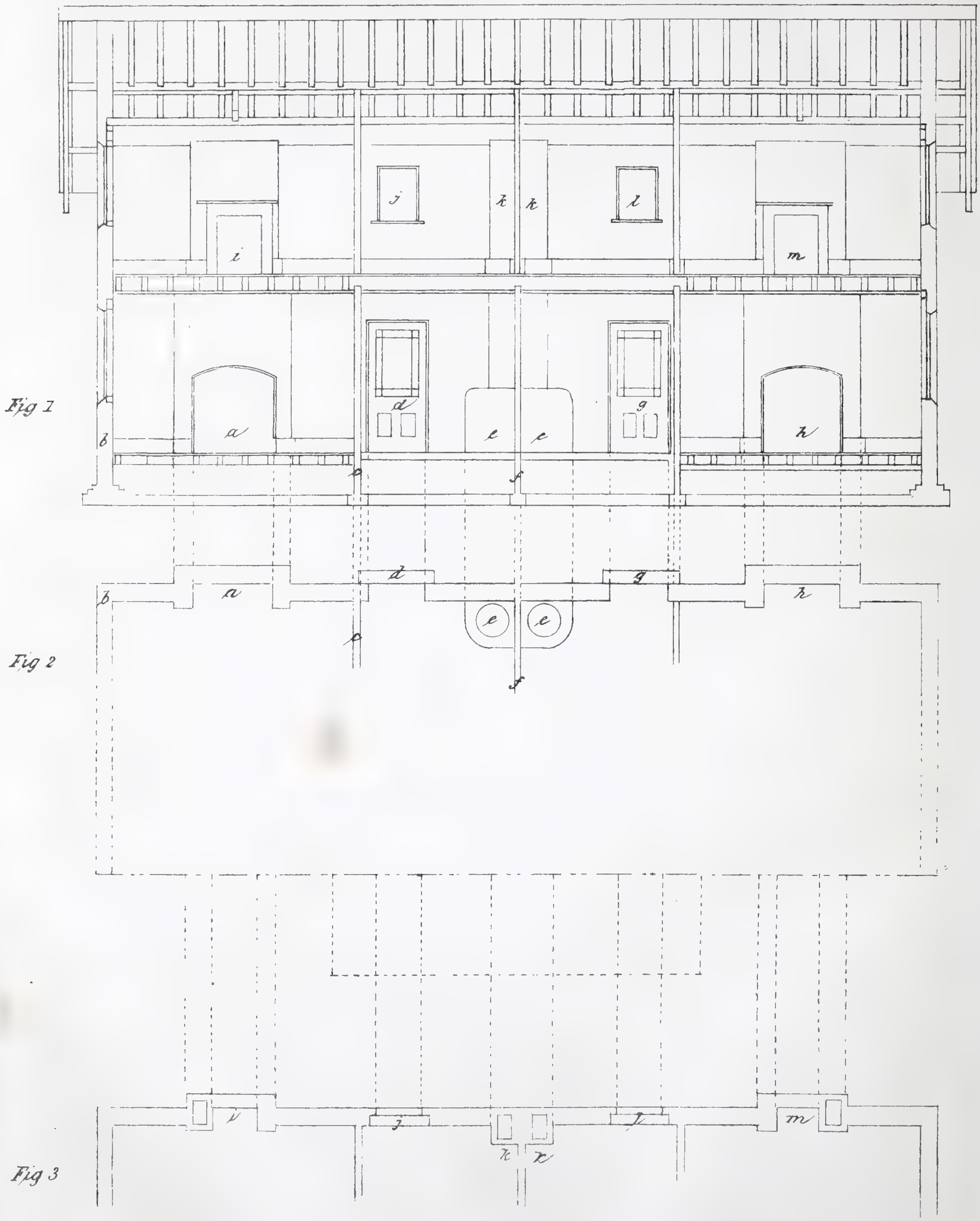
The first improvement upon the method of scouring, as domestically practised from time immemorial, was that of placing the vessel containing the goods above the vessel in which the lie was raised to a state of ebullition, the lie being raised by a pump to the top of the goods, through which it passed, and then re-entered the boiler. A great many different methods were afterwards devised, and Widmer of Jouy conceived the happy idea of employing the pressure of the steam itself to raise the lie. His very simple apparatus consists of a copper placed over a furnace, and fitted with a false bottom on which the goods are piled. A pipe passes down to within a very short distance of the bottom of the copper, and is fitted with a rose at its upper extremity to spread the lie equally. When in action, the steam generated below the goods and the false bottom presses upon the liquid, and causes it to rise up the pipe, whence it descends through the goods.

Another good apparatus is constructed upon the same principle as the last, except that the lie, in place of being heated in the actual scouring vessel, is raised to a boiling heat in an independent cylinder placed over a furnace, and communicating by a tube, with the bottom of the copper; whilst the pipe which descends to the bottom of the cylinder, serves to convey the lie to the top of the copper.

When the lie is made to boil, the pressure exerted on the surface of the liquid obliges it to rise by the pipe, by which it is discharged into the copper, filled with the goods to be operated upon; it passes through them, and finally regains the cylinder through the pipe.

This apparatus has the defect, easily comprehended, of not always furnishing the goods with a lie of a sufficiently high temperature: the cylinder, in fact, contains air together with the liquid, which air having no issue when it expands, presses upon the liquid and causes it to rise before it is sufficiently heated. To remedy this defect, recourse has been had to various modifications The pipe has been provided with a stop-cock to be opened at pleasure, and the return pipe, likewise with a valve, capable of being opened and shut at pleasure. Supposing that the first pipe is closed, the air and the generated steam having no issue but through the other pipe, the apparatus acts

PLATE F.



in the manner of the more simple ones already described; if, however, the valve be closed for a short time, the liquid will be heated under a much higher pressure than before, and the temperature will, consequently, be proportionately higher. If, after some time, we open the stop-cock of the first pipe, the liquid will be discharged with considerable force over the top of the copper. These modifications have the advantage of elevating the temperature of the lie to over 100° Centigrade; but, on the other hand, they give rise to considerable losses of heat consequent on the evaporation of the lie, which takes place immediately upon the removal of the pressure, and very great care and skill is requisite in the attendant.

The same inconveniences do not exist in the apparatus devised by René Duvoir (Péctet, *Treatise on Heat*, vol. ii., p. 282, pl. 95). By means of a couple of floats, which actuate an air valve placed in the boiler, and another valve placed at the mouth of the return pipe, a periodical ascension of the lie is produced of such regularity, that a determined quantity of lie per hour reaches the top of the copper.

Other apparatus on the circulating system are also employed, constructed, however, on different principles. A very simple one consists of a cylindrical boiler placed vertically over a furnace, and put in communication with a copper, in which the scouring is carried on by means of two pipes placed, one at the top and the other at the bottom of the copper, and in such a manner that the level of the liquid in the two vessels is easily kept equal. With this arrangement, it will easily be conceived that, the boiler being quite full of water, the application of heat below will cause the lower particles of liquid to expand and rise, being continually replaced by the lie flowing in at the bottom from the copper, whilst the heated water passes at the top from the boiler to the copper; in effect, a circulating current will be produced by the striving of the liquid to maintain equilibrium, which is disturbed by the alternate heating and partial cooling of its particles.

The next apparatus which we shall notice on this occasion, is one employed in the establishment of Dollfus Mieg of Mulhouse, and is something different from the preceding: the liquid is set in motion, however, by a very similar cause. By means of this apparatus, 500 pieces of calico can be scoured in 24 to 30 hours, and more when the goods are jaconets or muslins. It consists of the following parts:—boiler; tank in which the goods are placed; furnace; ashpit; platform for the attendants; furnace flues; pipe, up which the lie rises, fitted with a stop-cock; return pipe with a stop-cock.

The only object of the stop-cocks, fitted to the ascent and return pipes, is to cut off the communication with the boiler when necessary; there being in this case two tanks connected to the boiler, so that the operation is only carried on in one of them at a time, whilst the other is being emptied and refilled.

As in this apparatus the ascent pipe rises higher than the level of the liquid in the tank, it will not, at first sight, be comprehended how the circulation takes place; but a little attention will cause it to be easily understood. The tank and boiler being full of water, the lie in the ascent pipe attains a height equal to the level in the tank; the liquid in the boiler is then compressed by the column of liquid in the tank and in the pipe. When the apparatus is first put in action, the heat produces a difference in the density of the small quantity of liquid in the pipe, which, consequently, rises and passes into the tank. This, however, would not last long, unless there were not sufficient steam formed in the boiler to drive out the fluid by the ascent pipe.

This last apparatus has the advantage of bringing the lie to a very high temperature; notwithstanding which, it has several disadvantages in common with others of the same class: in the first place, it requires a very long time, 24 hours, in fact, being necessary for the treatment of 3,000 metres of common calico; secondly, when the goods are not very well arranged in the tank, there will be some parts to which the lie has freer access than to others, and the goods turn out, in consequence, unequally scoured; finally, as large masses are dealt with, the goods placed at the top of the tank receive the lie in a boiling state throughout the operation, whilst those at the bottom only receive it during a portion of the time; whence arise inequalities which have more or less influence throughout subsequent operations.

In taking the goods out of these various scouring apparatus, they are rinsed by mechanical means, which we shall shortly describe, after which they are passed through a second lie of pure lime. The residue of this second lie is generally employed for a succeeding first scouring, in establishments where the operations are carried on continuously and economically. After the second scouring, the goods are carefully rinsed, when they will be found to have lost all the soluble matters, as gum, lies, &c., which previously accompanied them, as well as a small portion of fatty matter, separated as calcareous soap, and a little resin; they merely retain the colouring matter, and the fatty and resinous bodies which are intimately incorporated with the fibre in a state of combination with the lime.

This point being reached, the goods are passed through an acidulous solution (diluted to 1° AB). Some employ sulphuric acid, others hydrochloric for this purpose. The operation is performed, sometimes by plunging the pieces, in bundles, into large tanks sunk into the ground, and filled with the acidulous solution; sometimes by passing the pieces singly through a trough, filled with the acidulous solution, surmounted by a reel, furnished with a handle, and into which fresh water and acid is put from time to time, to replace that carried away by the goods on the one hand, and to renew the acidity neutralised by the lime on the other. This operation is generally performed cold; but we have proved that the slight cost of fuel necessary to raise the temperature of these baths to 70° or 80° centigrade, will be more than compensated by the results obtained. We have, in fact, remarked that, at this temperature, not only are the calcareous soaps infinitely more thoroughly decomposed than at the ordinary temperature, but likewise that a portion of the colouring and resinous matter is dissolved by the acid, and carried off. In fine, the fatty acids set at liberty by the warmth react upon the resinous matters in the fabric, and combine with them in such a manner as to favour their solution in the ulterior bleaching processes. If our proposed modification be adopted, it may be carried out by employing a small furnace under a leaden trough, or by using steam in a wooden one. In the latter case, the bath will be fed by the condensed steam, and successive additions of acid will maintain the desired strength.

When taken out of this bath, the goods are carefully rinsed, and then submitted to soda carbonate lyes, in apparatus similar to those already described; the fatty acids combining then form a soluble soap, which, together with the excess of the carbonate of soda, dissolves the resinous bodies. When this scouring is well completed, and the goods freed from the liquid, the fabric consists solely of vegetable fibre, or pure *cellulose*, and a certain quantity of colouring matter, more or less modified, which remains to be carried away during the second phase of the bleaching processes—the decoloration, properly so called.

MECHANICAL DRAWING.

CHAPTER XIV.

Another method of describing the cycloid is given in fig. 109. Proceed as in last diagram, by dividing the half of the circle, $b\,c$, into equal parts, say twelve; and laying these also on the line, $c\,d$, to d, drawing perpendiculars from those meeting the line, $e\,b$. In place of describing a number of arcs, as in fig. 108, the points may be obtained through which to draw the curve by proceeding as follows. Draw through the various points, f, g, h, i, &c., in $c\,b$, horizontal lines, cutting c, a, b. With the distance from the line 3 to the point, g, on the line $g\,g'$, set off from the point where $g\,g'$ cuts the diameter, c, a, b, to the point, g', on $g\,g'$. From the point where the line, $h\,h'$, cuts the line 4 to the point, h, set off from the line, c, a, b, to h'. From the line 5 to the point, i, on the line $i\,i'$, set off from the line, c, a, b, to the point, i'. From the point on the line as 6′, set off to m; and with this distance set off on the line, $m\,m'$, from a to m'. Proceed thus, obtaining the points as

in the diagram, through which the curve is to be drawn by hand.

To draw the curve, the "epicycloid." This curve differs from the cycloid, in so far that the curve is generated by a circle rolling about another and fixed circle. In this case it is termed an "external epicycloid."

To describe an external epicycloid, as in fig. 110.—Let *a*, *b*, *c* be the fixed, and *o*, *d*, *e*, the rolling circle. Draw a line connecting the diameters, as *c e*. Divide the semicircle, *b e*, into any number of equal parts, as five; and also the quadrant of the large circle, *b f*, into the same number of parts. From *a*, with *a d*, describe a semicircle, *d d′*. From *a* draw radial lines through the points in the quadrant, cutting the semicircle, *d d′*, in the points. From these points describe circles equal in diameter to *e*, *d*, *b*. With the distance, *b* 1, from the point, *h* (at the point where the first radial line cuts the semicircle *d d′*) cut the circle described from the point, *n*, in the point, *o*. With the radius, *b* 2, from *m*, cut the circle described from the point, *p*, in the point, *m′*. With radius, *b* 3, from point *s*, cut the circle described from *t*, in the point, *p′*. With radius, *b* 4, from point *x*, cut the circle described from *v* in the point, 2′. With radius, *b* 5, from point *z*, cut the circle described from *w*, in the point, 3′. With radius, *b e*, from point *f*, set off 1′. Through the points, *o m′*, *p′*, 2′, 3′, and 1′, draw the curve by hand. The pupil had better draw this diagram twice the size, that is, the radius of his circle (fixed), *b c*, will be that of the moving circle, *e b*; the points of division will be farther separated, and more easily ascertained, and the crowding observable in a small diagram avoided.

An "internal epicycloid" differs from an external in the moving circle rolling in the interior of a fixed circle.—To draw the curve, *d g*. Draw any line, *d b*, from *a*, with *a e*, describe the semicircle, *b*, *e*, *d*. Let *b*, *c*, *f* be the moving circle. From *a*, with *a e*, describe a semicircle, *c c′*. Divide half of the small circle, *b*, *c*, *f*, into any number of equal parts, as seven, and divide the quadrant, *a*, *b*, *e*, into the same number of equal parts. From *e*, with radius, *b f*, lay off to *g*. With radius, *b* 6, from point *j*, cut the circle described from the point *l* in *k*. With radius, *b* 4, from point *m*, cut the circle described from *n*, in the point *o*. The operations are identical with those described in connection with fig. 110 (the external epicycloid.)

The "involute" is a curve described by the extremity of a thread, which is unwound from the circumference, being kept uniformly extended.

To describe the curve, as in fig. 112.—Let *a b* be the radius of the circle, and the point, *k*, the extremity of a thread wound upon the circle. Divide from *k* to *b* (having first drawn the radius, *a b*) into any number of equal parts. Through these points, *c d*, &c., draw lines from the centre, *a*. From the point where they touch the circle, draw lines at right angles to them; as, *k a′*, right angles to the line, *a k*, and *c b′* at right angles to the line, *c b*. From *c*, with *c k* as radius, describe a small arc to *l*, in the line, *c b′*. From *d*, with radius, *d l*, describe another arc, cutting the line, *d c′*. From *e*, with *e m*, describe an arc, cutting *e d′* in 1. From *f*, with *f* 1, describe another arc, cutting *f e′* in 2. From *g*, with *g* 2, describe an arc, cutting the line, *g f*, in 3. From *h*, with *h* 3, describe an arc, cutting *h g* in 4. From *i*, with *i* 4, cut the line *i h* in 5; and from *b*, with *b* 5, cut *b i*, in 6.

To describe the curve known as the "conchoid."—*f v*, fig. 113, is the "superior conchoid," *g w*, the "inferior conchoid." Draw any two lines, *a b*, *c d*, at right angles, cutting at *e*; from *b* draw any lines, cutting *c d*, as in the diagram. Make *e g* equal to *e f*, *h n* equal to *h m*, *s o* equal to *o p*, and so on, all the distances being equal to *e f* or *e g*.

To describe the curve, the "cissoid," in fig. 114.—Describe any circle, as *a b*, and at right angles to the diameter, *a b*, draw *c d*, touching the circle in the point, *b*. From *a*, draw any number of lines, cutting *c d* in any desired points on each side of *a b*. From *a* measure to *m*, and from *c*, with *a m*, cut the line *c a* in *m*. With distance, *a e*, from point 1, cut the line, *a* 1, in *n*. With distance, *a f*, from 2, cut *a* 2, in *o*, With *a g*, from 3, cut *a* 3, in *p*. With *a h*, from 4, cut *a* 4, in *s*. Draw the curve through these points.

THE COMPOSITION OF ATMOSPHERIC AIR.

M. Dumas presented to the Paris Academy of Sciences the results of the numerous experimental researches made by M. Lewy, on the composition of atmospheric air. These researches were undertaken by M. Lewy, during his residence at Paris, whilst on his journey to South America, and during his stay at New Granada, and were made both on the coast, and at an elevation of 3,193 metres above the level of the sea.

M. Lewy's analyses were made according to the process adopted by MM. Regnault and Reiset, which consists in analyzing the air by volumes. To ascertain the elastic force of the gases, M. Lewy employed an excellent cathetometer, constructed by M. Perraux, he was thus enabled to obtain the greatest possible degree of precision in his experiments; the greatest differences between two analyses of the same sample of air never exceeding $\frac{1}{10000}$, and, generally speaking, being not more than $\frac{1}{100000}$.

The different samples of air submitted to analysis by M. Lewy, were collected in glass tubes, the edges of which were filed off, and open at both ends. The tubes were of the capacity of about 100 cubic centimetres. The mode of filling them with air was as follows:—One end of the tube was connected by means of a caoutchouc tube with a small bellows, which was kept in motion during a sufficient length of time to insure all the air contained in the tube being replaced by the atmospheric air of the place where the experiment was performed, the most careful precautions being at the same time taken, to prevent any respired air being mixed with that intended for analysis. The tube, being filled with water, was immediately hermetically sealed.

On comparing one with another, the analyses made by M. Lewy, and which he has grouped in three categories, viz.,—those made at Paris during his journey, and at New Granada, it appears that the constitution of the atmosphere is almost the same in the New as in the Old World. On taking the mean of the analyses executed at eleven different localities in New Granada, it was found that 10,000 volumes of atmospheric air contained 4·008 of carbonic acid, 2101·425 of oxygen, and 7894·557 of nitrogen. These are the same proportions as those obtained by analyses of atmospheric air taken in different localities of Europe.

In carefully examining, however, these analyses, and, at the same time, taking atmospheric conditions into account, some interesting differences will be observed. Thus, in Europe, after a long season of wet weather, these researches show that carbonic acid and oxygen always exist in the atmosphere in less proportions than after a long drought; these differences, however, are appreciable only when the analysis is made with very great precision.

In the New World, where the seasons are more distinctly defined, these variations are more readily ascertained. During the fine season, the air always contains a little more oxygen and carbonic acid, than during the rainy season. Thus, on taking the mean of a great number of analyses, M. Lewy found that 10,000 volumes of atmospheric air at Bogota contained:—

	During the wet season, on a fine day.	During the dry season, on a cloudy day.
Carbonic acid...	3·822	4·573
Oxygen..........	2099·542	2102·195
Nitrogen	7896·636	7893·232

The difference, therefore, which exists between the composition of the atmospheric air of the two seasons, is a mean of 0·751 of carbonic acid, and of 2·653 of oxygen, in 10,000 volumes of air.

On taking the maximum and minimum of the results obtained in the analyses performed during the two seasons, we find for 10·000 volumes:—

	Wet season.	Dry season.
Carbonic acid...	3·609	5·043
Oxygen	2099·032	2103·199
Nitrogen	7897·359	7891·758

The greatest difference, consequently, is 1·434 for carbonic acid, and 4·167 for oxygen. These differences are sensibly the

same as those found by M. Lewy, between the analysis of the atmospheric air of Paris and of Havre, made under meteorological circumstances corresponding to the two seasons of South America. Hence it follows that the composition of the atmospheric air which we respire, whether in Europe or in America, is sensibly the same, as respects the relation between oxygen and nitrogen, with that which we respire at an elevation of 3,000 metres; the difference consists in the quantity of carbonic acid, which everywhere appears to be somewhat more in the air on the tops of the mountains, than in the valleys and at the level of the sea.

As regards the analyses of atmospheric air collected at sea, these have furnished M. Lewy with a very intersting result. During the day the air was constantly found to contain a little more oxygen and carbonic acid than during the night; this difference being the more appreciable the greater the distance from the coast. M. Lewy attributes this to the action of the solar rays, which, heating the water of the sea, disengage a part of the gases held by it in solution. It is well known that the air contained in sea water is richer in oxygen and in carbonic acid than the air of the atmosphere. The fact, however, is certain, whatever may be the explanation. In illustration, we may cite the following analyses of air collected on the Atlantic Ocean the same day, the same wind prevailing, and at a distance of more than 400 leagues from the coast:—

	At 3 o'clock in the morning.		At 3 o'clock in the afternoon.
Carbonic acid...	3·346	......	5·420
Oxygen..........	2096·139	......	2106·099
Nitrogen..........	7900·515	......	7888·481

The difference is thus 2·072 for carbonic acid, and 9·960 for oxygen, in 10,000 volumes of air.

The analyses of air made at New Granada have also sometimes shown an increase in the proportion of carbonic acid, coinciding with a diminution in the proportion of oxygen, admitting of ready appreciation. M. Lewy accounts for these alterations, by the emanations of the numerous volcanoes which exist in the New World, and also by the effect produced by the annual burning of the forests. It is, in effect, during this period that the constitution of the atmosphere presents these extraordinary changes. In those countries, these forest clearings are effected by means of immense fires, producing considerable quantities of carbonic acid, which, mingling with the air of the atmosphere, sensibly alters its composition. M. Lewy has found that the proportion of carbonic acid at these periods, sometimes rose to 49 in 10,000 volumes of air, or, in other words, ten times more than under ordinary circumstances. The diminution of oxygen, in the same circumstances, was often very considerable, amounting to 68·350 in 10,000 volumes of air. Thus, instead of 2101·425 of oxygen, only 2033·075 has often been found in 10,000 volumes of air.

LITTLE'S ELECTRO-MAGNETIC MOTION.

This is a contrivance for producing the rotation of a metallic ball, by means of a galvanic current. It will readily be understood from the annexed sketches and description.

P P of fig. 1 is the sole-plate of the apparatus. In the model from which the sketches were taken, it is simply a mahogany board of about 9 inches diameter, and adjusted horizontally by three adjusting-screws at *a a a*. A A are two small electro-magnets of the horse-shoe form. They are connected by wires with the mercury cups, B B, and by means of the magnets with the hollow centres, D D, which are the poles of the battery.

Fig. 2 represents the connections on the under side of the board, fig. 3. In this, A A are two bars of iron, which are attracted alternately by the magnets shown in fig. 1. B F are wires which dip alternately into the mercury cups, the board being supported upon the hollow centres, D D, of fig. 1, into which projecting centres (shown at D D, fig. 2) enter. The whole piece is nicely balanced on these centres, and vibrates easily upon them. But as the extremities, B B, of the wires, B F, B F, are made to project down at each vibration which the piece makes, the extremity of one of the wires is depressed into the cup of mercury immediately below it, at the same time that the other wire is elevated and withdrawn from the mercury of the cup beneath it. The other extremities, F F, of these wires pass through the board, and are attached to the inner metallic rail, shown as a circle broken at two points in fig. 3. In like manner, the ends, C C, of the wires leading from the centres, D D, pass through the board, and are attached to the outside rail, shown also as a circle broken at two points in fig. 3.

Between the rails shown in fig. 3, a metal ball, about $\frac{7}{8}$ inch,

Fig. 2.

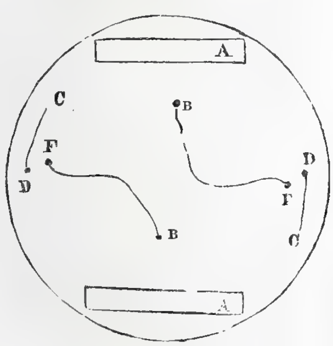


Fig. 1

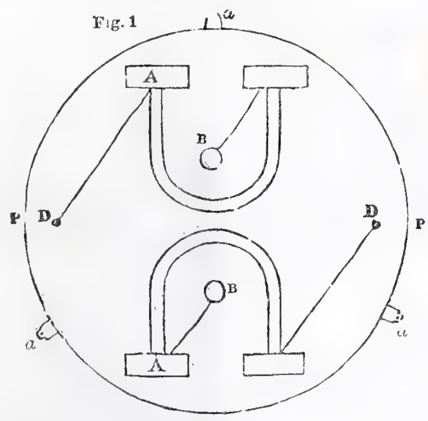
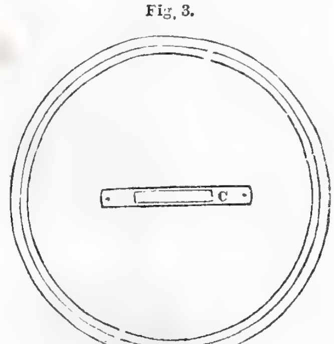


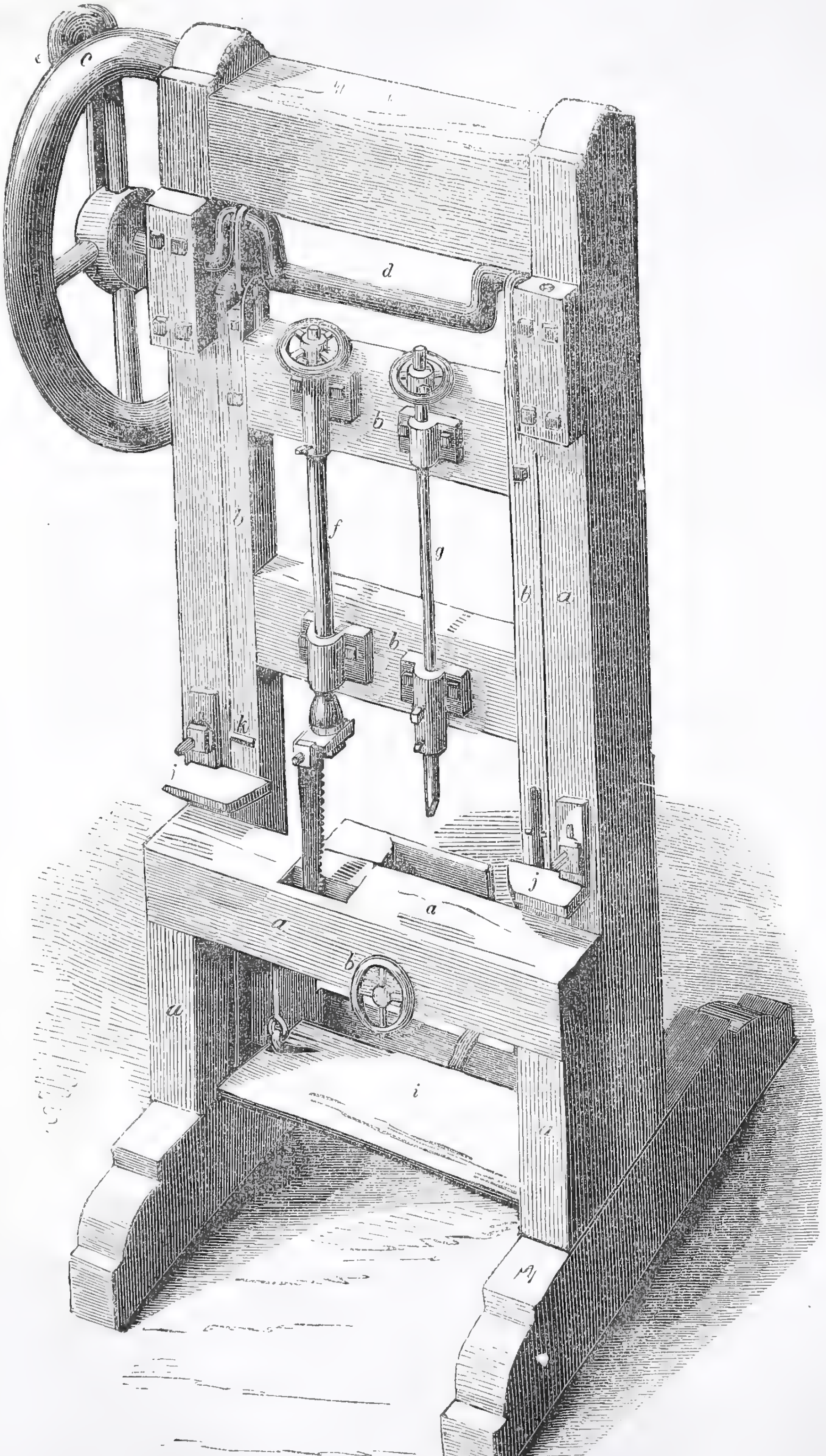
Fig. 3.



in diameter, is suspended, touching both rails at the same instant, and therefore completing the galvanic current through that half the length of double rail upon which it happens to be. But, from the arrangement pointed out, it is easy to see that the circuit being completed through one of the magnets, the bar of iron, A, immediately over it, will be immediately attracted; and the whole being supported only at the points, D D, that side of the board to which the attracted bar is fixed will be depressed and the other elevated. On this position being assumed, the ball must of necessity roll down the inclined plane, between the rails by which it is confined; but on passing from this division of railing to the next, the direction of the current will be changed; and passing through the opposite magnet, the corresponding iron bar will be attracted, and, in consequence, the side of the board to which it is attached will be depressed and the other elevated. The ball, rolling down the inclined plane thus formed, will pass, as before, to the succeeding division of rails, and, as before, will reverse the current, and, in consequence, the dip of the disc. In this way, the motion of the ball round the disc may be maintained so long as the action of the battery is sustained. A small spirit-level, C, is attached to the model, for the purpose of setting the disc horizontal in the line of the centres.

MORTISING AND TENONING MACHINE.

THE annexed engraving is a perspective view of an improvement in the above-named machines, for which a patent was granted to Elihu Street, Cincinnatti, on the 20th of March, 1854. The nature of the invention consists in the combination of certain tools used by carpenters in the manufacture of doors, sash, and blinds, in such a manner as to avoid loss of time occasioned by removing the work from one machine to another.



a represents the parts of a stationary frame, and *b* a slide frame. *c* is the fly-wheel, and *d* a crank-shaft connected to the slide frame by joints. *e* is a counter-adjustable weight to balance the slide frame, and *f* is a rod attached to a saw, and connected to a hand-wheel for tension, to adjust the saw. *g* is a rod attached to the chisel socket, having also a hand-wheel to adjust it; *h h* represents a sliding gauge operated by a hand-wheel. *i* is a footboard attached to the slide frame, to set the machine in motion. *j j* are movable stops. *k* is a plane-iron for jointing the ends of boards, &c. *l* is a plane-iron for tenoning.

The saw is fastened by screw bolts, and it can be taken off when not required, or be reversed, or turned out of the way when using other parts of the machine, and it can be set to cut at different widths. When using the chisel the saw should be reversed, and when using the saw the chisel should be removed or raised upwards, and fastened by one of the set screws. The counterbalance, *e*, gives effect to the working of the tools at the particular point desired. When using the smoothing plane, *k*, a board should be run forcibly against it, when it will be smoothed and jointed. The plane, *l*, for tenoning should be used in the same manner. The movable stops, *j j*, are for fastening down the lumber to the action of the tools. The hand-wheel, *h*, in front of the bench, is attached to the gauge by a rod having a screw; the rod runs through the bench, and by turning the wheel, the gauge is moved backward and forward by the screw. This gauge is used in mortising and sawing. The footstep, *i*, is attached with rods to the slide frame. By pressing with the foot downward upon it, the machine is set in motion—it is the stirrup for the foot to operate the machine.

The claim is for "mortising, tenoning, sawing, and smoothing, by combining certain tools together (in one machine), used by carpenters in the manufacture of doors, sash, and blinds."

BOTANY.

CHAPTER XV.

SECRETIONS CONTINUED.

Sugar.—That, in the ordinary progress of plant development, starch becomes changed into sugar, may be already manifest from the history of barley, which contains the one, and is found to pass, during germination, into the other. A similar transformation not only takes place in flowering, but the starch laid up in the body of plants in winter is turned into sugar by the flow of the vernal juices; and the fact allows of regular observation, that it is elaborated in most abundance when the season has been bright and warm. In that form, this proximate principle is found to belong almost properly to plants; for it enters only sparingly into animals, and seems restricted to that class which are furnished with organs of suck, and then has a composition resembling starch, for easy digestion and adaptation to the food of the young. Lactin, or sugar of milk, is obtained in colourless four-sided prisms, by evaporating the whey of milk to its crystallizing point; and though the substance is contained in no appreciable quantity in the blood of a healthy mammal, yet, in the disease called diabetes, the assimilating processes have failed to convert the saccharine aliment into the constituent principles of blood, and its presence in such cases becomes palpable both in the blood and the urine. Sugar is very generally diffused throughout the vegetable kingdom, and supplies the principal nutriment of the tender shoots of plants, for which purpose the elements of diastase operate in the buds. It almost invariably exists dilute in the interior tissues, but the flowers of certain species exhibit it in crystalline form. When concentrated, it possesses highly antiseptic properties, but serves a most important class of transitions by being prone to ferment when thinned with liquid. That portion which is natural to many fruits, as figs and raisins, forms a white incrustation on them, and is sufficient to insure their preservation dried. In jellies, and many medicinal preparations from plants, sugar is used to heighten the flavour or preserve the colouring principles, and even when added to meat and fish, it retains more of their natural taste, and renders less salt necessary for the keeping.

There are different kinds of sugar, which differ in the number or amount of their associated principles, and in their consequent capacities of solubility and combination. We now propose to treat of some of the sources from which the more considerable varieties, called by different names, are obtained.

1. Cane Sugar has not been traced to its nativity, but seems to have been earliest known to China and Hindostan. Dioscorides, among the Greeks, is supposed to refer to it when he writes of "a concrete honey, like salt in appearance and brittleness, and found in reeds growing in India and Egypt." It is also mentioned by Pliny and Galen. Its introduction into Europe, however, was not earlier than the age of the Crusaders, who had become acquainted with it during their adventures in Northern Africa and Syria. About the year 1420, it was carried by the Portuguese from Sicily into Madeira, but continued for some time to be a rare and costly luxury, as, in 1459, we find Margaret Paston begging her husband, a gentleman proprietor of Norfolk, that he would "vouchsafe to buy her a pound of sugar." Towards the end of the fifteenth century, the discovery of America by Columbus gave a stimulus to the transplantation of this vegetable in the Canaries and other islands of the West, though a sugar-bearing grass is known to have been indigenous to the new continent. About 1627, most parts of Europe were supplied by the Portuguese with Brazil sugar; but in or near to the year 1650, British planters in Barbadoes began to increase the cultivation of the plant, until, at length, every colony and island with an appropriate climate came to be engaged in the increasing branch of industry which it has opened up.

This valuable secretion has been procured in Italy from Sweet Sorgho (*Sorghum saccharatum*), and in Brazil from Gynerium saccharoides; but it is more generally obtained as a product from the genus Saccharum, including the species Sinense, belonging to China; Violaceum, to Tahiti and the West Indies; and Officinarum, to India—all now widely spread or interchanged over the hotter parts of the globe. In the East and West Indies, varieties are cultivated under the names of Country cane, Ribbon cane, and Bourbon cane, distinguishable from each other by the colour and length of their joints, and their form, firmness, foliage, and glumes. The stems are towards two inches in diameter, and vary in height from 6 to 20 feet. The outer part is hard and brittle, and green, yellow, red, purple, or striped externally; while the inner part is filled with a soft pith, saturated with sweet juice, which is elaborated in each of the granular joints prominently dividing the stem. From each joint is projected two rows of long narrow leaves, with a pyramidal pannicle of silver-grey flowers; but the best canes are those which have not flowered, or show no tendency to flower at all, and the lower parts of the trunk become denuded of both leaves and flowers as the canes approach to maturity. The usual mode of propagation is by slips or cuttings, taken from the top part of the cane, containing two or three joints. These are laid longitudinally in the bottom of well-manured furrows or trenches, and covered from the earth so banked up to the depth of one or two inches. Little by little, the earth is added as the sprouts begin to appear, until, at the end of four or five months, the whole has been filled in. This planting takes place intermediately from August to November, and when grown the slips get the name of Plant canes; but in the West Indies, several successive crops, even as many as twenty, under favourable circumstances, have been sometimes raised from the old roots, or stoles, as they are called, and the stems under this kind of culture are then known as ratoons. Though less vigorous than plant canes, the ratoons yield richer and more easily reduced juices, and, therefore, the old practice of obtaining one crop from plant canes and two from ratoons, has latterly given place to a greater dependence on ratoon crops, In twelve or fourteen months they arrive at maturity, when the skin has become dry, smooth, and brittle, the stem heavy, the pith greyish-brown, and the juices somewhat glutinous. They are usually cut in March or April, as near the ground as possible, on account of the secretion being in greatest abundance there, and the stumps are covered with mould. One or two of the top joints of the cane are reserved as food for cattle, and the rest is cut into short pieces of about a yard long, and immediately carried to the mill. After these lengths have been pressed for extraction of their saccharine contents, they are technically termed begass or trash, in which state they are still valuable, either as manure or fuel.

In the East Indies, the common mills for crushing canes consist of a built mortar, against the sides of which an inclined pistil rolls, formed of the trunk of a tree, and moved by oxen yoked to a horizontal lever connected with the summit. Lord Elphinstone, however, has recently set the example of introducing improved machinery into the plantations of Ceylon, and the rude mill is likely now to be gradually succeeded by that of more perfect construction. In the West Indies, vertical cane mills have been long in practice, and the irregularities or waste of their action have from time to time been redressed, until many varieties of horizontal rollers, made up of fluted cast-iron cylinders, have been brought successfully into use.

The freshly expressed juice of the cane usually amounts in quantity to about half the weight of the stem. It is a slightly viscid fluid, of dull grey or olive-green colour, sweet and balmy to the taste, and of specific gravity from 1·033 to 1·106. It usually suspends a quantity of solid matter from the cane; and the juice itself, besides sugar crystallizable and uncrystallizable, has been found by Proust, Avequin, and M. Plagne, to contain chlorophyl, gum, and gluten, wax and water, extractive matter, malic acid, acetate of potash, acetate, supermalate, and sulphate of lime, besides other salts, differing according to the nature of the soil. The lignin is for the most part separable by filtration and repose, and the other principles are more or less modified by after treatment; but the removal of those which contain nitrogen, such as the gluten and green fecula, tends sensibly to diminish the nutritive power of the sugar. The heat of the climate is almost always such as to cause this compound juice to pass with rapidity into the ace-

tous fermentation, often in about twenty minutes; so that the cutting of the stems not only keeps pace with the work of the mill, but the making of sugar from the sap commences with its flow from the stem.

The prevailing methods of separating sugar in the East are so tedious and defective, that the observations which follow must be understood as applying to the manufacture carried on in the West Indies. The first operation to which the juice is subjected is clarifying, by being conducted in a channel from the mill to large flat-bottomed coppers or open pans, capacious enough to contain from 300 to 1000 gallons each. It is usual to add a little slaked lime, called temper, to the juice in each pan, that the excess of acid may be neutralized; otherwise the crystallization of the sugar would be interrupted. The clarifiers are then acted on by a regulated heat from below, and, when the liquor has become hot, the solid portion of the juice is coagulated, and floats on the surface as scum. At this stage a damper is closed to extinguish the fire, and, after an hour's repose, the clarified juice has become clear, and of a yellow wine colour, and ready to be drawn off by a siphon or stop-cock to the evaporating pans, where the second part of the process awaits it. In these pans, three or more in number, and placed over a long flue, heated by a fire at one end, the bulk of the liquor is reduced, by long-continued boiling, to as thick a consistence as is necessary for granulation. The third step is to lade or skip this sirup into coolers, generally shallow boxes of wood, where it is crystallized. As the sugar is now brought to the state of a soft mass of crystals, imbedded in a thick viscid fluid incapable of crystallizing, their separation is effected in a large building called the curing-house, where the concrete sugar is allowed to drain, for three or four weeks, from a number of casks or hogsheads, with the spongy stalks of plantain leaf inserted in holes as filters. These casks are placed in an open framing of joists, below which a reservoir or cistern, lined with sheet-lead, boards, or cement, receives the blackish-brown fluid which escapes, called molasses or treacle. Some portion of crystalline sugar is held in this residuum, but has been redeemed by the discovery of certain precautions in the treatment, especially by moderating the heat during the first part of concentration. Its ropy tenacity adapts it for the retention of moisture. It consequently thickens very slowly under exposure to the air. It may be made to undergo fermentation, and in that state is largely employed for the distillation of rum. The imports of treacle into Great Britain in certain years, amount to about 600,000 cwts.

The sugar which leaves the curing-house is called by the synonymes—raw, brown, or muscovado sugar. Six pounds of juice in the East Indies, and eight pounds in the West Indies, yield one pound of this material. Sugar is commonly exported from our West Indian colonies in its raw condition, and loses often as much as 12 per cent. in weight, by drainage on shipboard of its remanent molasses. The purest samples, according to Christison, come from Demerara. When the quality is good, the small grains of which it is formed are shining, short, broken four-sided prisms, of a peculiar feeble odour, and from yellowish-grey to yellowish-brown in colour. Its clamminess has been ascertained by Daniell to arise from the lime which is mixed with its acid passing, by slow action, into the state of gum.

The other kinds of cane sugar are made from processes supplementary to the general operations now described. What is called refining, is, for the most part, practised in Europe from the raw imports, and, in Stow's "Survey of London," is said to have commenced in England about 1544. The former processes are all repeated in improved forms. For instance, to clarify it, the raw sugar is elutriated with lime-water, next brought to a state of solution by steam heat, then passed through filters, the interior of each being laminated with about sixty cloth or canvas tubes, to increase the filtering surface within the smallest compass, and is afterwards rendered colourless by descending through a bed of animal charcoal, resting on cloth at the perforated bottom of a vessel. Clay, blood, and alumina are also used. To the Hon. E. C. Howard is due the practice of evaporation in a vacuum, to enable the pan to boil at the low temperature of about 140° Fahr., instead of by a fire, as formerly, at a temperature of about 240°. The granulation is at last effected in an open vessel, around which steam circulates, and the sirup being transferred into rows of conical moulds, they are set up to drain, the extract being a kind of treacle called golden sirup. Clayed or Lisbon sugar, and white sugar-loaf, both result from these processes.

Among the chemical characters of pure sugar, are—a freedom from odour or aroma, whiteness, dryness, and easy power of pulverization. It crystallizes in small, oblique, four-sided prisms, with two converging planes, and in this form contains 5·3 per cent. of water of crystallization. When two pieces are rubbed together in the dark, phosphorescence ensues. Dr. Thomson gives its density as 1·5629. A late analysis by Peligot represents its composition as $C^{12} H^9 O^9$. Cruickshanks obtained, from a dry distillation, water, pyromucic acid, carbonic acid, and carburetted hydrogen; and in a distillation with lime, it yielded to Fremy a volatile liquid called acetone, and an oily substance termed metacetone. Water dissolves it in any quantity at 212°, and more than twice its weight at 60°. It is soluble in about twelve parts of rectified spirit, and only in eighty parts of alcohol. When exposed to a moderate heat, it parts with a small portion of hygrometric moisture. The crystals obtained in that case, by the slow evaporation of a strong solution to which spirit has been added, become large, yellowish-brown prisms, called candy, and in China and India are concentrated on small strings or twigs, from which they are afterwards detached. Candy, in short, is hydrated sugar in four or six-sided rhombs, or other derived forms, bevelled at the extremities. When heated to 365°, and cooled suddenly, the mass becomes barley-sugar, at first homogeneous, transparent, and glossy, but turning to opaque by keeping, and varying in colour according to the sugar used, and the dexterity of the manufacturer. By losing an equivalent of water at 400° to 420°, it is converted into caramel. At a red heat it burns with a vivid white flame, and at a higher temperature is decomposed, with gaseous disengagements and a large residue of charcoal.

Those who are desirous of obtaining fuller information are referred to Anderson's "History of Commerce;" Moseley's "Treatise on Sugar, with Medical Observations," 8vo., 1800; "Sugar Cultivation in Louisiana, Cuba, and the British Possessions, with an Examination of Minutes of Evidence on Sugar and Coffee Planting," 8vo., 1846; Evans' "Sugar Planter's Manual, being a Treatise on the Art of obtaining Sugar from the Sugar-cane," 8vo., 1847; &c., &c.

2. Maple Sugar is equal to the best cane, and may be obtained from the saccharine juices of all the maples; but the Acer saccharinum gives it most abundantly, and even smells of honey when in foliage. According to the younger Michaux, it is easily distinguished from the red maple, by applying to the wood a little of the solution of sulphate of iron, which changes the first into a green, but the other into a deep blue. This species prevails from beyond the northern boundary of St. John's, in Canada, to the south of upper Virginia, and clothes the best tracts in the territories of New Brunswick, Nova Scotia, Vermont, and New Hampshire. It attains a majestic stature, unlike the hardy maples which are cultivated in England, becoming in its native country, in many places, as high as eighty feet, and in autumn dyeing the woods with the crimson hue of its changing leaves. The wood of the tree is hard and satiny, and when occasionally waved in appearance, is in request amongst cabinet-makers. Its secretions, however, expose it very readily to the attacks of insects, by which it is often injured for ornamental purposes. When tapped for sugar, the spring season is selected before the snow leaves the ground, ranging from the beginning of February to the middle of April, and lasting during an actual passage of from four to six weeks. The south, and afterwards the north, side of each tree is perforated with an auger, in an ascending direction, for three-quarters of an inch, and this hole, as the tissues are drained, is gradually deepened to the extent of two full inches. Two or three such holes are inserted into the trunk about twenty inches from the ground, and into each opening a spout or tube of sumach or elder is introduced about half an inch, and made to project from three to twelve inches, for the pur-

pose of trickling the juice into kettles, troughs, or other convenient utensils placed underneath. The flow is regulated by the prevailing temperature. During warm days and frosty nights, its discharge is observed to be most copious; but it is daily removed to a receiver on the spot, strained, boiled down to a third of its original bulk, when it is converted into a sirupy substance, and, on cooling, gives out its molasses, and hardens into a fine brown sugar, which, if required, may be refined.

This cultivation is largely carried on in a great part of America. As much as 33 lbs. may be made from a single tree. Any settler may with ease make 300 lbs. for family use in the course of a season. Some even make 600 lbs., and others as much as 2000 lbs. Dr. Rush states, that the maple is uninjured by tapping, and has flourished after forty-two annual operations. The quantity, therefore, naturally supplied is such, that by forming and regulating plantations, a capacity to export might be arrived at after every local supply is insured. The labour is no other than what women and girls can bestow, and may be turned to good account by commanding anywhere in spring 4d. per pound, and, at other times, as much as 6½d. "To buy sugar with so prolific a source of it in the very woods that overshadow their habitations, is absurd; not to pay the land with such facilities of doing so, is even worse; and to cry out that they cannot live, with such rich beneficence offered to their hands, is wicked."

3. Beet Sugar may be extracted from the red root called Beta vulgaris; but it is chiefly taken from a variety of B. cicla, called the Great White Beet. Like maple, it has nearly the same composition, and, when well made, is equal in quality to the best cane sugar. Chaptal has described the process to consist of washing and scraping the roots; reducing them to pulp in a rasping machine; expelling the juice through canvas bags by a press; heating the liquid obtained in a copper to about 178° Fahr., stirring with lime-water, and adding animal charcoal, by which both a scum and sediment are separated; evaporating in shallow vessels until the sirup becomes thick, when it is strained through linen, and again boiled, skimmed, and cooled; and, at last, transferred to sugar moulds, where drainage takes place, and refining operations follow if necessary. The molasses which escapes is fitted to yield spirit, while the pressed pulp serves as a nourishing aliment to sheep and cattle. The roots weigh each from 10 to 20 lbs., and, when cleaned, produce about 4½ cwt. of coarse, or 160 lbs. of double-refined, or 60 lbs. of inferior, lump sugar.

This manufacture sprang up in France during the "continental system," which was a decree against the acceptance of English commerce during the wars of Napoleon Bonaparte; and, under the monopoly and premiums by which it was promoted, as many as nearly 200,000 acres have since been put under cultivation in France. There are also active manufactures in Russia, Prussia, and many of the German states. The enterprise, however, is said to be difficult of management, and, commercially speaking, has been found hardly profitable whereever colonial sugar is admitted at reasonable rates.

4. Grape Sugar is to be obtained in abundance from grapes, from which it takes its name, as typical of the saccharine constituents of many fruits, not merely fleshy, such as pears, cherries, peaches, melons, and dates, but chestnuts when growing in warm countries. It is produced from the metamorphoses of starch, as is shown by the action of an infusion of malt, brewer's wort, and fermented liquors in general. It is always present in the germination of seeds, and gives sweetness to gooseberries, currants, apples, plums, apricots, and most fruits. It exists both in a juicy and granulated form, the former in the interior tissues of plants, and the other in the nectaries of flowers. It has, however, less sweetness than the preceding sugars, and is composed, in its anhydrous state, of $C^{12}\ H^{12}\ O^{1}$. From this constitution, its elements undergo, in the process of fermentation, a simple conversion into alcohol and carbonic acid; and Guerin Varry has shown that these products are exactly equal in weight to the anhydrous sugar employed, according to the formula $2C^4\ H^6\ O^2 + 4C\ O^2$. Cane sugar, even in its hydrated state, is incapable of undergoing a similar change, being incapacitated by one equivalent too little of water ($C^{12}\ H^{11}\ O^{11}$). A spirituous distillation, on the vastest scale, may thus be supposed to pervade the vegetable kingdom, meted out, in determinate supplies, to every plant, and affecting each vessel at once with a stimulant and antiseptic action. In familiar illustration of the fact, the writer has often witnessed, in the heat of summer, wasps and other insects that had preyed to the full on luscious gooseberries under waste, either drop down suddenly in a sprawling condition, or make off in a short staggering flight, from the measure of alcohol evolved having sufficed to intoxicate their nervous system.

Honey may be considered as grape sugar altered by insect mastication. The material is collected by different kinds of bees; but, in Europe, chiefly by the neuters of the Apis melifica, or hive bee. After being sucked up by their proboscis, it descends through the œsophagus, until elaborated in the honey-bag; and, being disgorged, is deposited in the cells of the comb somewhat modified in its sensible properties. The plants from which it is derived impart to the preparation their peculiar attributes; and a honey, frequently poisonous, is extracted from the Rhodoraceæ, such as Azalea, Rhododendron, Kalmia, &c. In the peninsula, named by the Greeks the Thracian Chersonésus, now called the Crimea, also in some parts of North and South America, honey is of this noxious description. Heather honey, and that from most labiate plants, is entirely wholesome, and, except where there is gastric or intestinal irritation, is a salutary article of consumpt. But even this variety is subject to fluctuation from the mode of its preparation. When pressure has been applied to the comb, impurities become mixed up with it from the wax, or bee bread, so that an inferior collection is brown in colour, bitterish to the taste, and of disagreeable odour; and it is a well-known fact in pharmacy, that such a coarse kind of honey is liable to putrefaction from the decay of its azotiferous ingredients. Schmidt recommends, as the most effective mode of purifying honey, to "boil it gently with a third of its volume of water, and a sixteenth of its weight of ivory black, not too finely powdered; to let the grosser particles of charcoal subside, and remove the rest by filtration through flannel; to clarify the liquor with white of egg; and to concentrate the filtered liquid over the vapour-bath to a due consistence." Virgin honey is the name applied to the drippings of the comb from the hive of young bees before they have swarmed. When pure, it is dissolved by boiling alcohol, and deposits, on cooling, crystals of grape sugar. But besides grape sugar, it is composed of uncrystallizable sugar. It is thick and viscid; but, from a fluid state at first, is apt to concrete into granulated crystals. It is colourless, or of pale straw colour, sweet and fragrant. By undergoing vinous fermentation, it yields a strong spirit, which passes by the names of hydromel, metheglin, or mead. It is soluble, in great measure, in water, in which state it is demulcent, emollient, and refrigerant, and, when combined with vinegar and borax, forms an efficacious gargle in apthæ of the mouth and throat.

5. Liquorice Sugar is the produce of certain herbaceous plants belonging to the order of pea-flowered Exogens, in the natural family Leguminosæ of Decandolle, or Fabaceæ of Lindley. Several of these plants secrete an abundance of sweet mucilage; thus, Berzelius traced its principle in the roots of Abrus precatorius, Trifolium alpinum, and Astragalus ammodytes; and the same property is also found in other species of the last genus, in Onobrychis sativa (Saintfoin), and in the leaves, root, and inner bark of Robinia pseudo-acacia (False acacia). But it is from the genus Glycyrrhiza, or Liquorice proper, that the saccharine matter is chiefly obtained in practice, and it is yielded in common by the species glandulifera, echinata, and glabra. The second species is a native of the Crimea in the south of Russia, and, though possessing no more than between 30 and 40 per cent. of sweetness, and a middle degree of characteristic yellow and compactness, is recognised for its officinal qualities by many of the colleges on the Continent. Trommsdorff obtained in it a little uncrystallizable sugar, and found a principle which fermented with yeast. G. glabra gives out the largest proportion of sugar, amounting to between 50 and 58 per cent., and it is from this species that

the common liquorice of the shops is with us obtained. It has a long, succulent, creeping root-stalk, from which arise several stems from two to four feet high and upwards. The leaves are large, unequally pinnate, yellowish-green, and in pairs, terminated by an odd one; and both leaves and stalks are somewhat viscous and clammy. The flowers are in axillary spikes, whitish, with purple tips, and give place to short pods containing from two to four seeds. This species is a native of Germany, but to be met with in France, Spain, Italy, and some parts of Austria. Stow affirms that it was introduced into England in the first year of Queen Elizabeth (1558), and in Turner's Herbal its cultivation is referred to as already established there in 1562. It is at the present time extensively grown about Pontefract, in Yorkshire, where the name of Pomfret cakes is applied to one of its preparations; at Worksop, in Nottinghamshire; in Godalming and Mitcham, in Surrey, and also in the gardens about London. The English produce is said to be thinner in the skin and less worm-eaten than that imported from the Continent. The person who lately wrote in the *Glasgow Herald* under the signature of Senex, says he saw it raised for sale in that city, by an apothecary, at the end of last century. The plants may be produced either from seeds or from a division of the root-stalk, containing from eight inches to a foot in length, with an eye-bud at the end. In this last case, the sets, about the beginning of March, are inserted perpendicularly by means of a stick at the distance of one foot and a half from each other, and in rows two and a half feet separate, every alternate row being intermediate with the positions of those beyond, in quincunx form. Though raised in the field, the plants require a garden culture. A mellow black mould, as fine as sand, to the depth of three feet, and smoothly levelled up, lightness, warmth, and nourishing manures, are necessary to their perfection. Hoeing down the weeds in summer, delving betwixt the rows in autumn, at the beginning of winter spreading rotten dung over the crowns of the plants, in spring again turning over the spaces betwixt the rows, and during the time after, keeping the ground clean of weeds, comprise the careful tillage, of which it has been said (Green's Herbal, i., 624), "the husbandman may rest assured, that by every shilling he would save in not having this work well performed, he would lose ten at least in the crop." At the end of three years, the root-stalks are fit for consumpt, and, attaining to the length of several feet, and to half an inch in thickness, the produce in general is most exuberant. The odour of the root-stalk is faint but pleasant. Lade gives its composition, when pure, as $C^{18} H^{24} O^{7}$. Lignin, as a matter of course, forms a great part of its substance. The presence of a resinous oil, soluble in water only with the aid of heat, and giving rise to a sub-acrid taste, has been detected in the greyish-brown bark. Starch, wax, albumen, earthy phosphates and sulphates, malic acid, an azotized crystalline substance, analogous to asparagus, called agedoïte, and the principle of sweetness peculiar to liquorice, termed glycion or glycyrrhizin, are, according to Robiquet, the remaining constituents. Berzelius obtained glycion by precipitating, with sulphuric acid, a concentrated infusion of the root; then washing the precipitate with water acidulated with sulphuric acid, and afterwards with a little pure water; dissolving the remains with alcohol, and neutralizing that solution with carbonate of potash; and, on evaporating the filtered fluid to dryness, the substance that remained was transparent, brittle, uncrystallizable, and intensely sweet. Glycion is soluble both in water and alcohol, but differs from common sugar in not yielding oxalic acid when treated with nitric acid, and in being unsusceptible of vinous fermentation. It swells up under the action of heat, and, at a higher temperature, gives out a clear white flame.

Water being a good solvent of the active principles, the liquorice root-stalk, when cut into small pieces or bruised, is either infused warm or macerated cold in medical practice. When boiled, the proportion of water ought to be a pound by measure to one and a half ounce of the root. Then strain; but the boiling, if longer continued than ten minutes, is apt to elicit rosin to the deterioration of the taste, which is so justly esteemed. When percolation with cold water is employed, a much finer extract is obtained than by decoction. For this purpose, the roots are first cut into chips; then dried, and reduced to a moderately fine powder. A commercial preparation, of foreign manufacture, formed by inspissating the decoction in copper kettles till the mass is thick enough to firm on cooling, is well known in this country under the name of black sugar or sugar-alice. It is prepared from the roots both in Sicily and Spain; but the finest extract comes from Italy, stamped with the name Solazzi, a celebrated maker there. It is made up into rolls or cylinders called sticks, each six to eight inches long, brownish-black, smooth and shining, dry, brittle in cold, but tenacious in warm weather, and usually enveloped in a covering of bay leaves (*Laurus nobilis*), to obviate contact in packing. Water dissolves from three-fifths to eleven-twelfths of it, according to quality; but, when pure, it should be entirely soluble in the mouth. The little rolls, about the thickness of a crow quill, which are sold as refined, contain good liquorice, with a mixture of gum or gelatin; the usual adulterations and impurities arise from the addition of gum or starch, plum juice, and earthy or metallic matters. Where many of these admixtures do not arise from the slovenliness of the makers, a little copper may be necessarily present from the pans in which the extract is boiled, as well as from the constitution of the plant itself, in which Zier found that metal in the proportion of about a 50,000th part.

Liquorice root is extensively used by porter brewers. It has, besides, a valuable application as a pectoral, and not only promotes expectoration, but mitigates the pain of diarrhœa and urinary irritation. It is the only sweet substance that is known to allay thirst without drinking, and, on that account, is often beneficial in dropsies. Amongst its indirect uses, it is a successful vehicle for the administration of nauseous drugs.

6. Manna belongs to the saccharine series of vegetable bodies, and, like these compounds, is very extensively distributed. The term, as applied to sugar, is of Hebrew origin, and is a mere vocalization of the word, מן, a rad, מנן signifying portion. Various opinions have been entertained as to the precise nature of the substance which, to a large extent, composed the food of the Israelites in the wilderness. The scriptural marks assigned to it are as follow:—Exodus xvi. and Numbers xi., it descended with the dew at night in a powder like hoar-frost; the colour was that of the bdellium; like the coriander seed, white; and the taste thereof like cakes with honey. It melted by the heat of the sun while lying in the field, or, if kept in that state, rapidly putrefied by breeding worms; but after it was housed, it acquired so hard a consistence as to be ground in a mill, or beaten in a mortar, when it was baked in pans into cakes, the taste of which was of fresh oil. It must be confessed that all these characters are conformable to the idea of evaporated pollen, subject in its descent to insect attacks, and undergoing changes according to the action it was subjected to. We learn from positive sources, that, in Arabia Petræa, a sort of condensed honey, of volatile nature, is still to be found on the leaves of trees and herbs, and even on the rocks and sand; and that, in the neighbourhood of Mount Sinai, it receives a strong aroma from the plants on which it falls. The name manna, however, has been extended to a local exudation from many trees occupying different parts of the world; such as, Larix cedrus of Lebanus, Tamarix gallica of Sinai, a species of Camel's horn, related to Alhagi maurorum, growing in Persia and Bokhara, and Eucalyptus mannifera of New Holland. Burckhardt says, that in the valley of Ghor (the Jordan), a manna, provincially known as "Assal Beyrouk," or honey of Beyrouk, drops principally from the sprigs of a plant called by the Arabs the Gharrab; and that it is collected by the natives, who convert it into cakes. But, in modern nomenclature, the term is especially applicable to the concrete juice of several species of Ash, generically termed Fraxinus, according to Linnæus; or rather Ornus, as afterwards detached from that genus by Persoon. Different authors have adduced the O. parvifolia, O. subrufescens, and O. lentiscifolia, as capable of yielding manna of various qualities; but, according to Tenore, there are two varieties of the O. Europea, called rotundifolia and garganica, which are specially cultivated for the fineness of their manna. These are all inhabitants of

the South of Europe, as Sicily, Calabria, Apulia, &c.; and the commercial supply is chiefly imported from Messina and Palermo. The trees are usually from twenty to thirty feet high, of elegant appearance, and adorned in May and June with clusters of white flowers. The juice, thickening on escape, exudes either spontaneously, in small white grains, from fissures produced by the weather, or from the punctures of an insect infesting the trees—the Tetragonia orni—or more generally from artificial incisions, about three inches long, longitudinally inserted in the bark. The harvest commences in July, and lasts for three or four months; but the quality of that exuded in October is inferior. It either diffuses itself on the branches, or trickles on the ground, or on leaves spread out to receive it; and when no precautions are taken to insure its purity, the masses become irregular or party-coloured, and more or less mixed up with bark or sand. The finest variety comes from Calabria, collected on straws or twigs, in flakes about one inch broad and six inches deep, of pale yellowish-white, dry, brittle, slightly odorous and sweet, but also bitter, and, on the whole, unpleasant to the palate. The heat of the hand is adequate to reduce it to softness, and it melts at a temperature a little higher. It is soluble in water, but less readily in rectified spirit.

Assuming the juice of the Ornus to be the standard of the current manna, we must here notice the peculiar principle called mannite, to which its sweetness is owing. The result of its analysis by Rose, Pelouze, and Liebig, gives about 60 per cent. of mannite, about 32 per cent. of moisture, and of crystalline and uncrystallizable sugar, colouring extractive, and probably gum, each a little. Its composition is set down as $C^6 H^7 O^6$. The mannite is procured by boiling and evaporating an alcoholic solution, when four-sided prisms, colourless and tufted, are left. It is sweet, without smell, and not fermentable though mixed with water and yeast. A mixture of oxalic and mucic acid is produced when treated with nitric acid.

In addition to the plants we have noticed, mannite has been considered to be present in celery. The following table has been drawn up by Dr. Stenhouse, to represent the per centage of mannite in certain sea-weeds:—

Sea-weeds.	Per cent. of Mannite.		
Laminaria saccharina,	12	to	15
Halydris siliquosa,	5	"	6
Laminaria digitata,	4	"	5
Fucus serratus,	proportion less.		
Alaria esculenta,	do.		
Rhodomenia palmata,	2	to	3
Fucus vesiculosus,	1	"	2
Fucus nodosus,	nearly the same.		

This saccharine principle is also afforded by various species of Fungi. It has been detected by Knop in Agaricus piperatus; and other kinds of mushroom may be seen in our woods during the latter end of summer, blackened over by the Musca carnaria, or Maggot-fly, probably attracted by properties arising out of this source. Cantharellus esculentus and Clavaria coralloides have been also adduced as containing mannite.

In respect to the uses of manna, its nutritive qualities are recognised by serving for food in the countries where it is collected. With us it is one of the mildest of laxatives, and esteemed for its remedial powers in the febrile disorders of children and persons of weak habits, especially if abdominal irritation prevails. The flatulent tendency which it sometimes exhibits, is corrected by combination with an infusion of senna, rhubarb, or other medicine more active than itself.

Other Neutral Principles, like the preceding group, composed of carbon, oxygen, and hydrogen, are for the most part of lesser moment in a practical point of view. Great difference is observed as to their quantity in particular plants, and they seem to give character to the secretions sometimes of families of plants, and frequently of chains of families. The subjoined list embraces a few of the more well-known examples:—

Meconin, Narcotin, Narcein, Porphyroxin,	...... from	Opium.
Piperin,	"	White pepper.
Picrotoxin,	"	Coculus indicus.
Elaterin,	"	Elaterium.
Cubebin,	"	Cubebs.
Digitalin,	"	Foxglove.
Caffein and Thein,	"	Coffee and tea.
Asparagin,	"	Asparagus, Althæa root, &c.
Hordein,	"	Barley.
Amygdalin,	"	Bitter almond.
Phloridzin,	"	The bark of the roots of apple, pear, plum, &c.
Salicin,	"	Various species of Salix, or Willow.
Absinthin,	"	Wormwood.
Cnicin,	"	Blessed Thistle.

8. *Lignin* is the white fibrous mass which remains when an herbaceous stem newly cut is reduced to powder, and all its soluble parts are removed by successive boiling in water, alcohol, ether, and diluted acids or alkalies. It varies, among different plants, in colour, hardness, and specific gravity. Its texture is full of pores, in which the juices resided, and, when both juices and air have been extracted, it becomes heavier than water. Beet-root and turnips contain only about three per cent.; but, in the harder kinds of wood, the proportion is far higher. When its soluble contents are kept dry or nearly evacuated, the power of wood to resist decay is very great. Decomposition follows upon exposure to alternate wet and drought; but, when either are made uniform, a piece may remain entire for centuries, as in the mummy coffins of Egypt, some of which have been estimated at 3000 years.

By treatment with strong sulphuric acid, lignin may be reduced to gum, and, on this mass being boiled in water, grape sugar is generated. All its products in the same way, such as sawdust, linen rags, or paper, allow of being transformed into sugar. No sooner, accordingly, is a bud tipped with green, than the sugar which nourishes the parts that convey sap to the growing parts is changed into woody fibre. "Thus the sugar of the ascending sap of the maple and the alder disappears in the leaf and in the extremities of the twig; thus the sugar-cane sweetens only a certain distance above the ground, up to where the new growth is proceeding; and thus also the young beet and turnip abound most in sugar, while in all these plants, the sweet principle diminishes as the year's growth draws nearer to a close."—*Johnston's Elements*, &c., p. 29. The same writer explains the progress of this change in living plants thus (Pp. 187, 188):—" In the blades and stems of the young grasses there is much sugar, which, as they grow up, is gradually changed, first into starch, and then into woody fibre. The more completely the latter change is effected, that is, the riper the plant becomes, the less sugar and starch its various parts contain. It is ascertained, also, that the weight of the hay or of the straw we reap, is actually less when they are allowed to become fully ripe; and therefore, by cutting soon after the plant has attained its greatest height, a larger quantity, as well as a better quality, of hay will be obtained, while the land also will be less exhausted. The same remarks apply to crops of corn, both to the straw and to the grain they yield. The rawer the crop is cut, the heavier and more nourishing the straw. On the other hand, the ear, which is sweet and milky a month before it is ripe, gradually consolidates, the sugar changing into starch, and the milk thickening into the gluten and albumen of the flour. As soon as this change is nearly completed, the grain contains the largest proportion of starch and gluten; but if the crop be still left uncut, the next natural step in the ripening process is to cover the grain with a thicker skin. A portion of the starch of the grain is changed into woody fibre, precisely as in the ripening of hay, of the soft shoots of the dog-rose, and of the roots of the common radish. By this change the quantity of starch is lessened, and the weight of husk increased; hence the diminished yield of flour,

and the increased produce of bran. Theory and experience, therefore, indicate about a fortnight before full ripening as the most proper time for cutting corn." In reference to these remarks, we beg only to explain that bran is a portion of lignin.

It may appear from all this, that it is to lignin plants owe their hardness and solidity. It constitutes, in fact, the skeleton of, and gives mechanical support to, their structures. It is the basis of woody fibre. Cellulose is the name of its substance, forming the parietes or walls of all cells, and this is insoluble in water. It is also called amygdaloid, with a reference to the cotyledons of leguminous and other seeds; and vegetable jelly, in respect to the cell walls of sea-weeds, &c. But from a delicate transparency in cells, it becomes, by development, hardened into deposits of incrusted matter throughout the races of plants; and when it has attained to this dense form, according to Rodget (An. and Veg. Phys., i., 62), it has a larger proportion of carbon and hydrogen, and less oxygen than the primitive tissue of the simple cells and vessels. It becomes thus a permanent deposit, incapable of further alteration or removal to other parts of the woody system, as is the case with nutritive matters of a more convertible kind. The operation of blanching, among certain cultivated vegetables, has for its design to prevent or modify its formation.

FARRIERY.

CHAPTER VI.

THE PASTERN AND FOOT, WITH THEIR BONES AND INTEGUMENTS.

Immediately under the knee, at the back of the shank, and in the interval between the two splint-bones, two remarkable and important ligaments are found; extraordinary from the circumstance of their being elastic, and important from their admirable adaptation for obviating concussion. They take their rise from the head of the shank-bone, and likewise from the heads of the splint-bones; from thence passing down the leg, they fill the groove between the splint-bones, but are not attached to either of them: a small way lower down they expand on both sides, and when near the pasterns they divide, and are inserted into two little bones, which are situate at the back of the upper pastern, one on each side, and are termed the sesamoid-bones. These will be understood by referring to the figure 4, in Plate VII., which represents a section of the bones cut longitudinally. These form a sort of joint, both with the lower head of the shank-bone and the upper pastern-bone, to both of which they are attached by ligaments, *a*, *b*, but much more firmly united to the pastern than the shank-bone. The flexor tendons pass down between them through a large mucous bag, which prevents the friction that would otherwise ensue in so contracted a situation. The ligament is continued over the sesamoids, and afterwards obliquely forward over the pastern, and unites with the long extensor tendon, and downwards to the perforated tendon, which it surrounds and fixes in its place, and likewise to the smaller pastern-bone.

The lower portion of the shank-bone or metacarpal-bone, *a*.

The upper or larger pastern-bone, *b*.

The lower or smaller pastern-bone, *c*.

The coffin-bone, *d*. This bone is situate within the hoof, and nearly resembles it in form; it occupies about half of the fore part of the hoof, and nearly resembling it in form, being half-moon shaped: it is convex above and in front, and concave behind and in front. It varies, however, with the natural form of the hoof, and adapts itself to such changes as are induced by a diseased state of the hoofs. It is of a light and spongy texture, and numerously perforated with small holes, which are fitted for the passage of the blood-vessels of the foot. These are beautiful provisions of nature for preventing pressure, and enabling the blood to circulate freely. But for these, these vessels would be frequently subjected to great pressure, which would prevent the free circulation of the blood, and bring on inflammation of the parts. It will be noticed that the upper surface is concave, for the reception of the rounded termination of the lower pastern. At the back is a depression for the perforating tendon.

The sesamoid-bone, *f*.

The suspensory ligament, *g*.

The tendon of the perforating flexor inserted into the coffin-bone, after having passed over the navicular-bone, *h*.

A lengthened ligament reaching from the pastern-bone to the knee, *i*.

The small inelastic ligament which fastens down the sesamoid-bone to the larger pastern, *j*.

The extensor tendon, which is inserted into both the pasterns and the coffin-bone, *k*.

A continuation of the suspensory ligament inserted into the smaller pastern-bone, *l*.

The navicular or shuttle-bone, *m*. One of the principal uses of this bone, is to take off a portion of the weight from the coffin-bone; and from the navicular-bone it is thrown on the tendon which rests on the elastic frogs beneath.

The inner or sensitive frog, *n*. Its form is wedge-shaped, projecting from the bottom of the foot, as well as the substance continued from it, and occupying the interval between the cartilages.

The ligament which unites the navicular-bone to the smaller pastern, *o*.

The ligament which unites the navicular-bone to the coffin-bone, *p*.

When there is lameness in the navicular, it proceeds from this quarter, *q*.

The sensitive sole between the coffin-bone and the horny sole, *r*. It is situate between the coffin-bone and the sole; and from its yielding consistency, assists in preventing concussion, and also yields a supply for the horn of the sole. It is provided with nervous fibres, and is extremely sensitive. That lameness which is brought on by the pressure of a stone, or of the shoe on the sole, is occasioned by inflammation in the sensitive sole. Those corns which occur between the crust and the sole proceed from the same cause.

The coronary ring of the crust, *q*.

The covering of the coronary ligament, from which the crust is secreted, *r*.

The sensitive laminæ to which the crust is attached, *s*.

The crust or wall of the foot, *t u*.

The part for bleeding at the toe, *v*.

The horny sole, *w*.

The cleft of the horny frog, *x*.

From the situation which the suspensory ligament occupies, it is obvious that splints formed backwards on the leg are more liable to produce lameness, than those which are situate on the side of the leg; for this reason, that they interfere with the free action of this ligament by pressing upon, and wounding it. The principal action of these ligaments is in concert with the sesamoid-bones, which they appear to suspend in their places; and hence their appellation—the suspensory ligaments. The pasterns are united to the shank in an oblique direction, which inclination differs in degree in the various breeds of horses, and which is best suited to the species of labour the animal is destined to perform. The weight falls upon the pastern in the direction of the shank-bone, and the pastern being articulated obliquely, a portion of the weight must necessarily be communicated to the sesamoids. The oblique direction of the pasterns and their yielding, saves much jar; and the concussion which would be occasioned by that portion of weight which falls on the sesamoid-bones is completely obviated, because there is no bone underneath to receive it. They are suspended by this ligament, which is elastic, and gradually yields to, and is lengthened by, the force impressed upon it, and in this gradual yielding and lengthening, all painful or dangerous concussions are rendered impossible.

As the ligament lengthens, the sesamoid-bones, it will be found, descends, when they are subjected to a weight being thrown on them. In the thorough-bred horse, which has long pasterns, it will be seen that the tuft at the fetlock will be some inches from the ground when he is standing; but when he is in the act of galloping, which throws a weight suddenly and violently on this joint, the tuft descends and sweeps the

turf. This is caused by the combined action of the fetlock and pastern joints, together with the sesamoid-bones. The sesamoids do not really descend, but they revolve or partly turn over. The strong ligament by which they are united to the pastern-bones, performs the office of a hinge; and the projecting portion of the bone to which the suspensory ligament is united, turns round with the pressure of the weight, and that part of the bone becomes the lower. It will be asked, how is it raised again? This ligament, strangely constructed as a ligament, is elastic; yields to the force to which it is subjected, and lengthens; but so soon as the foot is raised from the ground, and the weight no longer presses, and the force is removed, its elasticity is exerted, and it resumes its former dimensions by contraction, and the sesamoid-bone springs back into its place, and, by that forcible return, assists in raising the limb. This is the opinion of Mr. Percival, who says—"Furthermore, it seems to us that those elastic parts assist in the elevation of the feet from the ground, in those paces in which they are called into sudden and forcible action. The suspensory ligament, by its reaction instantaneously after extension, aids the flexor muscles in bending the pastern joints. The astonishing activity and expedition displayed in the movements of the race-horse at speed, seem to be referable, in part, to the promptitude with which the suspensory ligaments can act before the flexor muscles are duly prepared: the latter, we should say, *catch*, as it were, and then direct the limb, first snatched from the ground, by the powers of elasticity."

The length and obliquity of the pastern varies in different breeds of horses, depending principally on its slanting direction; and according to the extent of this obliquity will depend the amount of springiness, and the consequent ease of its paces. The pastern must be long in proportion to its obliquity, otherwise the fetlock would be too close to the ground, and, when the horse is going at speed, would come violently upon it. The fetlock must be elevated a certain distance from the ground, and this is effected either by its being short and upright, or long and slanting; and in this produces two consequences: less weight will be thrown on the pastern, and more on the sesamoid; and, in that proportion, jarring or concussion will be prevented, and the jar of the weight, which is thrown on the pastern, will be lessened by the very obliquity of the bones. In the race-horse, it should be long and oblique; less so in the hunter, somewhat shorter in the hackney, and considerably less in the dray and cart horses. In the latter two, the concussion is very little, because their movements are slow; and their pasterns being short and upright, they are enabled to drag and sustain heavy loads, to a much greater extent than other horses. But an upright pastern is a very great defect in a horse that is to be used for the saddle, as it not only renders him unsafe—being liable to come down—but likewise very disagreeable in riding, his paces being so hard; and, in all probability, will be soon attacked with ossification of the cartilages, ringbone, and contracted feet. In a saddle horse, therefore, with ordinary work, a little too much obliquity of the pastern is a far less evil than one that is too upright; as the jolting produced by it is a most disagreeable nuisance to the rider, is most injurious to the horse itself, and renders it liable to many diseases in the legs and feet.

BONES OF THE FOOT.

Plate VII., Fig. 3.

This is a representation of the back of the bones of the pastern joint, and the foot, and those connected with it. The coffin-bone constitutes its osseous fabric, to which the navicular-bone may be regarded as an appendage. It is of great importance to understand thoroughly the anatomy of the bones of the pastern, as it is so much concerned in the action of the horse. It is so liable to diseases from its constant use, and the great weights it has frequently to sustain.

FRONT VIEW OF THE PASTERN.

Plate VII., Figs. 5, 6, 7.

The coffin-bone, or *os pedes*, *a*. This bone is of a half-moon shape, convex before and above, and concave below and behind.

The navicular-bone, or *os naviculare*, *b*.

The lower pastern, or *os coronæ*, *c*.

The upper pastern, or *os suffraginis*, *d*.

The coffin-bone with its horny laminæ, *a*. It is situated within the hoof, and is similar to it in form, its outline being crescent-shaped. It varies, however, in form, according to the shape of the hoof, or by disease in it. The coffin-bone is of a soft spongy substance.

The navicular-bone, or, as it is sometimes called, the shuttle-bone, *b*. It is situate at the back of the coffin-joint, and enters into its composition. It is crescent-shaped; its lunated border will not, however, make above one-third of a circle of such dimensions. One of its extremities takes an outward direction, and the other inward: their joints are obtuse, and are fixed by lateral ligaments to the coffin-bone.

The lower pastern, or coronet-bone, *c*. It is situate between the pastern and the foot, and corresponds to the second phalanx of the human foot. It is nearly of a square form.

The upper pastern, *d*. It is situated below the cannon-bone, with which, taking an oblique direction, it forms an obtuse angle. It is connected with the cannon and coronet bones, and also with the two sesamoid-bones.

The sesamoid-bones, or *os sesamoidæ*, *e*. These are placed at the back of the articulation formed by the pastern and cannon-bones. They are articulated only with the large metacarpal bone, and are connectd with that and the pastern-bone.

THE NERVE, VEIN, AND ARTERY OF THE PASTERN AND FOOT.

Plate VII., Fig. 8.

This represents the situation of the vein, artery, and nerve, after having been operated upon during various diseases to which the foot is liable; affections which produce a great degree of pain to the animal. This is technically termed Neurotomy, or cutting of the nerve. The nerve will be seen on the inside of the foot, as it approaches the fetlock, and passing over the pastern. Branches are given off above the fetlock, which proceed to the fore part of the foot and give it feeling: its continuation, under the fetlock chiefly, supplies the quarters and hind part of the foot. It is of much consequence that the true position of the following should be known:—

The sole of the foot, *a*.

The horny crust, *b*.

The fleshy or sensitive laminæ, *c*. These cover the coffin-bone, the horny crust being removed.

The posterior lateral ligaments, *d*.

The internal or sensitive frog, *e*.

The branch of the nerve, which supplies the fore part of the foot with feeling, *f*.

The lower part of the vein before the artery, *g*.

The same vein spreading over the pastern, *h*.

The continuation of the nerve, *s*, and proceeding downward to supply the back portion of the foot with feeling, *i*.

The extensors of the foot, *j*.

The deeper flexor tendon continued downward, called the *perferans*, or perforating tendon, and contained within the other, *k*.

The division of the nerve on the fetlock joint, *l*, *m*.

The tendinous band in which the flexors work, *n*.

One of the flexor tendons, *o*.

The deeper flexor tendon, *p*.

The artery between the vein and nerve, *q*.

The vein before the artery, *r*.

The nerve on the inside of the off-leg, at the edge of the shank-bone, and behind the vein and artery, *s*.

ATTACHMENTS IN FRONT OF THE PASTERN-BONES, &C.

Plate VII., Fig. 9.

The coffin-bone, *a*.

Branches of the suspensory ligaments proceeding to unite with the extensor tendon, *b c*.

The back of the upper pastern, *d*.

The back of the lower pastern, *e*.

The back of one of the sesamoid bones, *f*.

The lower part of the shank-bone, *g*.

The lateral cartilage of the foot, *h*.

The ligaments connecting the two pastern-bones together, *i*

EXTERNAL PARTS OF THE FOOT.

A beautiful proof of design is manifested in the formation of the foot of the horse, which admirably fits him, as well as the ass, for the peculiar service of man; the uncleft hoof enabling him to perform services for which the cleft hoof is utterly inadequate.

CRUST OR WALL OF THE FOOT.

The wall or crust is that portion of the hoof which is visible when the foot rests upon the ground, ending above where the hair terminates. Its front is called the toe, and is greatest in depth, becoming gradually more shallow at the sides, which are denominated the quarters, and its utmost back extremity is called the heel. When the sole is placed on the ground, the crust displays an angle of about forty-five degrees, differing more or less in various individuals, but the nearer what we have named, viz., the fourth part of a cemicircle, the more perfect is the crust considered. When the obliquity is of a greater degree, it is said that the crust has fallen in, and when the sole is too flat, it is said to be pumiced, or convex; and when the front is more upright than the angle above named, it indicates a contracted hoof, in which case the sole will be too concave. When the crust is deep at the heel, the foot will be liable to thrush, contraction, sand-crack, and inflammation; besides, the pastern will be upright, and, consequently, the paces of the horse hard and unpleasant. If the crust diminishes too rapidly in depth, and the heel is low, it will be found that the slant of the pastern will be too great, and hence a disposition to sprain of the back sinew; the entire foot will be liable to weakness, and subject to bruises, and likewise a tendency to that obscure, although frequent malady, called the navicular-joint disease. The foot having spread out too wide at the sides instead of grooving upwards, is, therefore, too much exposed, and liable to disease.

The crust in front is somewhat more than half an inch in thickness, and becomes gradually thinner as it approaches the quarters and heels. Consequently, if there be but half an inch for nail-hold at the toe, and still less at the quarters, we need not be surprised if horses are occasionally wounded in the act of shoeing; especially when horses are frequently very restive under that process. This fact will show that the shoeing of a horse should only be intrusted to skilful hands, as many fine horses have been rendered lame for months in consequence of a nail being driven through the fleshy portion of the foot. Even with the best shoeing farriers this will happen, and therefore the animal should always be carefully examined after being shod.

The circumstance of the crust being a little higher and thinner in the inner than the outer quarter, is a wise provision of nature; because, being situate under the inner splint-bone, more of the weight rests on the inside than the outside; therefore it has the property of expanding more, and, by its elasticity, assists in lessening concussion. Consequently, when expansion is prevented by the inner quarter being nailed firmly to the shoe, it is almost certain that corns, contraction, and sand-crack will be induced. The crust is not liable to great variation of thickness, as will be seen by a reference to Plate VII., fig. 8, except near the top at the coronet, or where the horn of the hoof unites with the skin of the pasterns, where it suddenly becomes thin, as will be observed by reference to *b* in fig. 8.

At this point it seems as if scooped out, and here likewise its colour and consistence are changed, and appears as if it were a continuation of the skin. This thin portion is what is designated the coronary ring, fig. 1, and which covers a thickened prolongation of the skin, termed the coronary ligament, *s*. This extension of the skin is supplied with numerous densely-set blood-vessels, united by a fibrous texture, many of which have the property of secreting the horny substance which forms the crust. The sensitive laminæ, *s*, have likewise the property of secreting horn, which furnishes an immediate defence against injury in cases where the crust is either intentionally removed, or has sustained external injury. This is manifest in sand-crack or quitter, when it becomes necessary to remove a portion of the crust. A pellicle of horn, or of thin hard substance resembling it, soon covers the wound; but the crust is chiefly formed from the coronary ligament. Consequently, sand-crack, quitter, and other diseases, in which strips of the crust are destroyed, is very long of being renewed by growing down. It must proceed from the coronary ligament, and so gradually creep down the foot with the natural growth or lengthening of the horn, of which, as is the case with the human nail, only a sufficient supply is slowly given to compensate for the wear and tear of the part.

The crust is composed of numerous fibres, which, at the toe, run in a straight direction from the coronet towards the sole; but, at the quarters, proceed in an oblique direction from the heel forwards. This arrangement is best adapted for enabling the foot to expand when it comes in contact with the ground, and, by that expansion, permitting the gradual descent of the bones of the foot, and, consequently, preventing much concussion. The crust is thinner at the quarters and towards the heels, because those are the parts at which the principal expansion must take place. These fibres are kept together by a gelatinous substance, but in such a manner as to permit a slight degree of separation, or to bestow the power of expansion on the foot; and when recently separated from the foot, it will be found that the substance is exceedingly elastic and very tough, as a preventive against chipping or breaking with the violence to which it is too frequently exposed.

Many horses are very liable to brittle hoofs during the summer, which is a great defect; and it not unfrequently happens, that so much of the hoof is gradually broken away, that there is not sufficient hold for the nails left. A composition of one part of oil of tar, and two of common fish oil, well rubbed into the crust and the hoof, will restore the natural elasticity and toughness of the horn, and contribute much to the quickness of its growth.

In the healthy state, the wall of the hoof should be smooth and level: when there are protuberances or rings round the crust, they indicate that the horse has had inflammation in the feet; and that to such a degree, as to induce an unequal growth of horn, and probably to leave some injurious consequences in the parts under the hoof. If there be a depression or hollow in the front of the foot, it indicates sinking of the coffin-bone, and a flat or pumiced sole: if the hollow be at the quarters, it is the worst degree of contraction.

We have represented the crust and its various component parts at Plate VII., figs. 9 and 10, which will give an idea of their structure.

The external crust or wall, *a*, which is also seen at fig. 10, *a a*, and at *h* and *i*, fig. 9, is the rounded portion of the heels belonging to the frog of the foot.

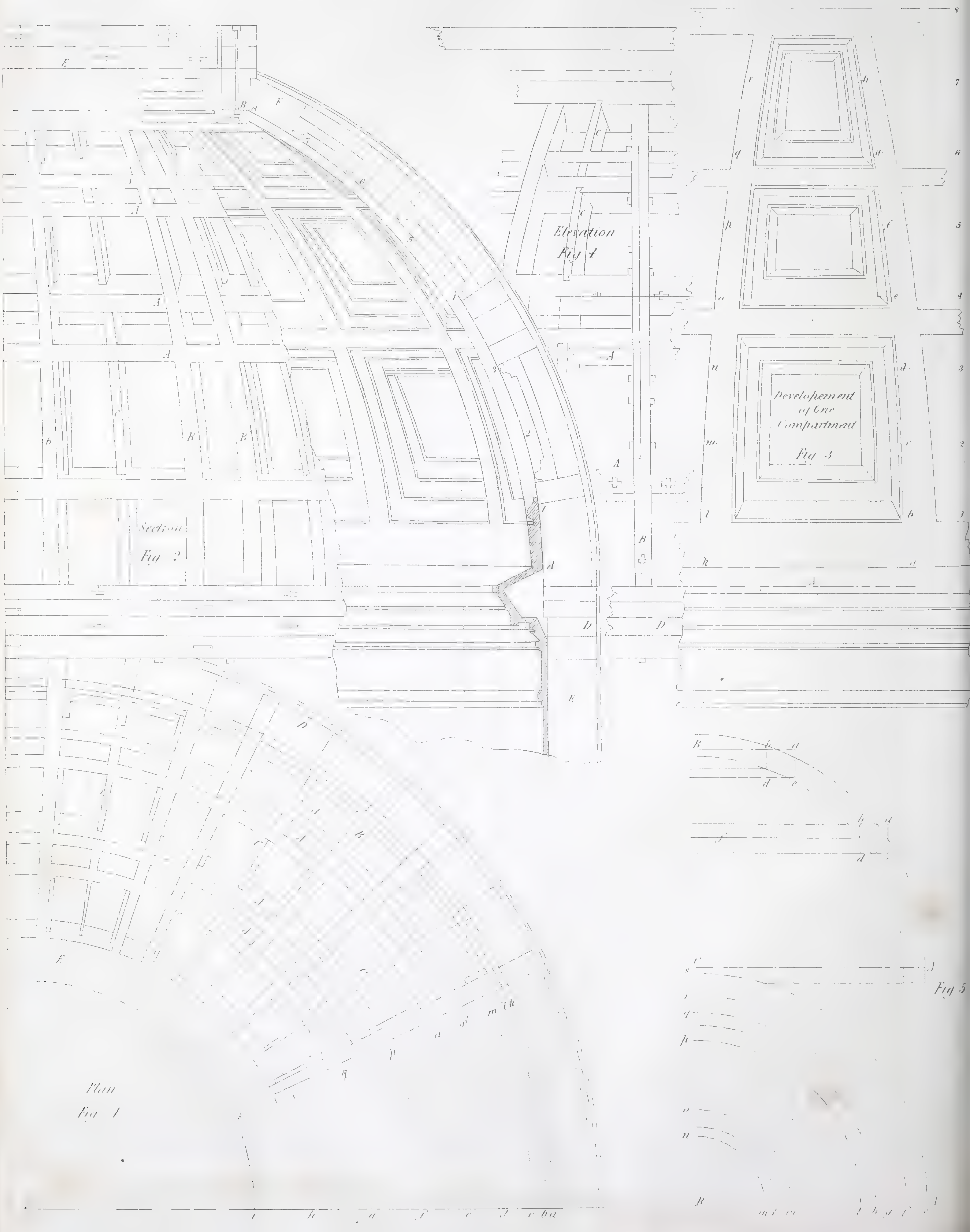
At *l*, fig. 12, is the external surface of the sole, or the arched plate, which enters into the formation of the bottom of the hoof, and covers the entire surface of the foot with the exception of the frog.

In the operation of shoeing, the utmost attention should be paid to the sole, as upon the paring and defence of this horny plate entirely depends the perfection or defect of this operation. When the sole is inspected from below, it generally exhibits an arch of more or less concavity, in which respect it is subject to infinite modifications in degree of the arc. In some hoofs it is a complete flattened surface, and, strange to say, both seem to perform equally well. The sole in the hind feet is generally more arched than in the fore, and its form nearer the oval than the circle. The sole is about one-sixth of an inch in thickness, but that portion most elevated from the ground—that which forms a union with the bars—is nearly double the thickness of the central or circumferent parts; and next to this in substance comes the heel, which is situate at the back part of the foot, at which point the crust of the hoof, instead of being continued round and forming a complete circle, is abruptly bent in, which will be seen by referring to fig. 10, and likewise at *h*, fig. 9.

THE CARTILAGES OF THE FOOT.

These are two broad, scaly-surfaced, concavo-convex cartilaginous plates, which rise above the sides and wings of the coffin-bone. There is a groove extending along the upper

Cradling for Domes



part of the coffin-bone on each side, except at the protuberance, which receives the extensor tendon, and which extends to the extreme posterior portion of the foot, emanating from the quarters fully half an inch above the hoof, and diminishing in height backwards and forwards. These cartilages occupy the larger portion of the foot, exceeding the coffin-bone, which will be seen in fig. 1, Plate VII., *a*, where, it will be observed, they extend considerably behind the coffin-bone and the flexor tendon, by which means they are rendered perfectly secure. Below these are other cartilages connected with the under edges of the former, as well as on both sides of the frog.

The sensible frog is situate between these cartilages, occupying the entire space, and performing several important functions; it acts as an elastic bed or cushion, on which the navicular bone and tendon can play with security, and without being exposed to concussion. This will be readily comprehended by referring to fig. 4, Plate VII., *v*. By these means all concussion to the cartilages of the foot is prevented, and the cartilages kept apart from one another, and the expansion of the upper part of the foot preserved. The importance and beauty of this mechanism is a striking proof of design. The elastic and yielding substance of the frog is pressed upon by the navicular bone, as also the tendon and the pastern, and, as it is incapable of condensing into less compass, is forced out on each side of them, and expands the lateral cartilages; and these again, by their inherent elasticity, revert to their former situation, when they are no longer pressed outward by the frog. It consequently appears that, by a different mechanism, but both alike admirable and referable to the same principle, namely, that of elasticity, the expansions of the upper and lower portions of the hoof are effected, the one by the descent of the sole, and the other by the compression and rising of the frog. The usefulness and preservation of the limbs of the horse are chiefly maintained by this upward expansion, when the destructive methods, which are practised in shoeing, are calculated to destroy the expansion beneath. In consequence of the long-continued and violent pressure on the frog in draught-horses, and conveyed from the frog to the cartilage, inflammation is frequently induced, which too often terminates in the cartilages being converted into bony matter.

THE FALSE CARTILAGES.

The false cartilages take their rise from the lower and back portions of the true cartilages: they are fibro-cartilaginous in their substance, and extend in a forward direction towards the heels of the coffin-bone. They spread inwards upon the surface of the *tendo-perforans*, become united at their inner sides with the superior margin of the sensitive frog, are covered below by the sensitive sole, and, at the same time, assist in supporting the sensitive frog. Their form is triangular, and they are arched in the same manner as the sole. Their use seems to be to fill up the triangular vacant spaces left between the *tendo-perforans* and the heels of the coffin-bone, by which means the surface of support of the sensitive frog is completed, and likewise for the purpose of extending it for the expansion of the sensitive sole. In such situations bones must have proved inconvenient, by more or less impeding the impression upon, and the consequent reaction of, the sensitive frog.

BUILDING ARTS.

CHAPTER VII.

THERE is danger, however, in making the drains too small; the recent researches into the cause of the epidemic which raged in Croydon with such deadly effect, elicited much valuable information in connection with house drainage. The engineer, Mr. Page, who was called upon to investigate the engineering details of the drainage which had been carried strictly out in accordance with the plans promulgated by the Board of Health, thus investigates the soundness of the illustration which we gave at the end of the last chapter. He thus proceeds:—

"No one will doubt the correctness of this reasoning in favour of the 4-inch pipe, as far as it goes; but, unfortunately, it does not go far enough; for if *two* scrubbing brushes, or *two* hearth stones, or any two of the various classes of substances which are washed into the pipe sewers, should be supposed to meet in the 4-inch pipe sewer, into which so many 4-inch house drains discharge, then the 6-inch or 8-inch pipe would have the advantage over the 4-inch pipe; and if each of the numerous house drains were to supply simultaneously its contribution towards an obstruction, whether it were a "nightcap" or a "piece of flannel" or a "kitten," or any one of the stoppages at Croydon, then not only would the 10-inch or 12-inch pipe be insufficient for the conveyance of these matters to the outfall, but the 11-inch pipe also; and as in many of the districts drained, whether by pipes or brick sewers, the habits and knowledge of the population are such as to render them averse to, or unfitted for, such sanitary arrangements as require systematic treatment—and as the population cannot hastily be fitted up for the sewerage, the sewerage must be fitted up in a degree for the population—another important element, besides the simple hydraulic one, forces itself, or ought to force itself, upon the attention of those who are laying down maxims for such important improvements as sewerage and drainage, namely, *the requirements of the population for whom the works are intended.*"

A wide range of experience in the use of pipe drains seems to prove pretty decidedly, that they should not exceed 500 feet in length, the inclination being not less than 1 in 200; that, with the exception of courts or pavements, no road or street drainage should run into them, nothing but the house sullage; that the smallest sewer pipes should not be less than 9 inches diameter, or larger than 12 inches, and the drains leading to these pipe sewers from each house should be of 6 inches diameter. A pipe 9 inches diameter, laid as a sewer in a small court, will be sufficient to receive the drainage of from three to six houses.

However much discrepancy of opinion exists as to the requisite size of house drains, of comparatively small number, there seems to be little or none as to the street sewers; the general opinion being, that they have hitherto—until a very recent period—been constructed of far too large a size for the fluid they were intended to convey. One cause, probably, of the great size to which they attained, even in comparatively unfrequented streets, was the ignorance existent among artizans, to whose conduct such operations were generally left, as to the increase of capacity of hollow bodies in proportion as their diameter increases. Thus, at first sight, it might appear correct to state, that a tube, twice the diameter of another, would contain twice as much, whereas in reality it would contain four times as much; just as a square piece of wood, 4 inches on the side, contains four times as much as one 2 inches: $2\times2=4$ in the one case, $4\times4=16$ in the other. Hence we can easily understand how it is that a builder, knowing that a house, or range of houses, which experience showed required a drain, say of two feet diameter, would at once decide that a drain, four feet diameter, would be required for a house, or range of houses, twice as large; whereas he would have a fourfold capacity instead of a twofold, as he might have calculated on.

As useful at this stage of our inquiry, we here give the rule for finding the capacity or cubical contents of cylindrical bodies, of which the diameter, the length, or height are given. "Square the diameter, multiply it by ·7854, multiply this by the length or height." Example—Required the contents of a tube 12 inches diameter and 6 inches high (cub. in.):—

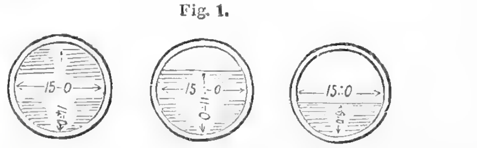
$$12\times12=144\times7854=113{\cdot}0976\times6=678{\cdot}5856.$$

The cubic inches being found, the gallons can be known by dividing the product by 277·274, the number of cubic inches in a gallon.

Another cause of the enormous dimensions to which sewers have attained, was the ignorance of what may be called "hydraulic paradoxes." "One of these last is the fact, that a

uniform, sufficiently sloping, open channel, which, at its top, is freely receiving from a reservoir, or a meeting of currents, so much water as completely to fill its mouth, can yet receive into its stream lower down, large additional quantities of water through lateral inlets, and will then discharge from its bottom opening, which is of the same size as the top opening, even several times as much water as entered at the top." Another of these "paradoxes" is the fact, that if a common funnel, or a short piece of tube with a gaping mouth, be held under a water-cock, and as much water be allowed to fall into it as to maintain it nearly full, and if then a pipe of the same diameter as the lower outlet of the funnel or piece of tube be joined in it so as to lengthen it below, the quantity of water passing through, instead of being lessened by the friction of the additional downward pipe, as happens when an addition is made of horizontal pipe, will be increased in a proportion to the length of pipe added, until that length reach a level of about 34 feet below that of the mouth of the apparatus. A water column of 34 feet has a pressure nearly that of the atmosphere. The first of these remarkable facts is a simple consequence of the law known to everybody, that a body falling freely is always increasing its speed, whether its course be directly down, as of an apple from a tree, with increase of speed of 32 feet per second, or be oblique, as when a railway carriage carelessly left loose at the top of a steep slope gets away, and soon has a velocity which dashes it to pieces against any obstacle met below (the increasing speed, in such a case, being proportioned to the steepness of the slope or incline); and whether the descending body be solid, as in the cases just mentioned, or fluid, as in the water of a perpendicular cascade, or in the rapids shooting along sloping portions of a river channel. The phenomenon of the acceleration of a fluid current, under the continued influence of gravitation, is well shown where a viscid fluid like treacle is poured from a height. A mass, at first slow moving, and as bulky as a man's wrist, may be seen gradually tapering as it descends to the size of a finger or less, the diminution of size being everywhere exactly proportionate to the increase of speed; and however long the experiment be continued, the tapering cascade retains the same form. Similarly, a water stream, in a sufficiently sloping uniform channel, becomes less bulky as it descends and as the speed increases; although, of course, the same quantity of water passes along every portion of the channel; and hence a larger space or area of the uniform channel is left unoccupied by the water as the speed of this increases, and so more room is left for additional streams to enter the channel from around its descending course. Because, however, friction of the water against the sides of the channel increases rapidly, as the speed of the current increases, while the force of gravity tending to accelerate remains the same; a state of equilibrium is soon reached between these opposing forces, after which the stream, however long, goes on uniformly, with speed proportioned to the slope. This is seen in all rivers of uniform current. In the annexed woodcut, fig. 1, are sketched sections

Fig. 1.



at three points of a sloping pipe, in which a stream was running, and becoming less bulky as the speed increased. The other hydraulic paradox, above mentioned, of a common funnel or gaping short piece of pipe (and in certain cases of water drains), being caused, by having an addition of pipe made at the lower opening, to transmit much more water than what fills the mouth, which pipe may be either perpendicular or oblique, is owing to the disturbance of the atmospheric pressure, which is acting on all things at the surface of the earth, and therefore on the top and bottom of the column of water in the pipes. It happens thus:—In the cases supposed, the descending stream, if free, would quicken its speed, and become lessened in bulk in its descent (as already explained above for open channels, or for free descent in the air), but in a long tube, having openings only at the top and bottom, and both openings filled with water, the stream cannot lessen its bulk without leaving a vacuum in the tube, which vacuum the pressure of the atmosphere at the top and bottom tends to prevent. Thus, therefore, the part of the tube below, as well as that above, is kept full of water, the weight of which balances or destroys more or less of the upward atmospheric pressure at the lower opening, and lets the undiminished atmospheric pressure above act, as an unopposed force, to urge more water through. If the tube below had its mouth exposed to the air (that is, were not immersed in water), and were roomy enough to allow a stream of air to ascend by the sides of the stream of water descending, no increase of water flux through the general tube would be produced by an addition of tube below.

In illustration of the above, may be given the following instance of one trial:—

"Velocity and amount of water flowing through 235 feet of 15 inch earthenware pipe, temporarily laid at Hitchin, at an inclination of 8 inches in the 235 feet, or 1 in 352½, an opening being made for the admission of air at the centre of the pipe."

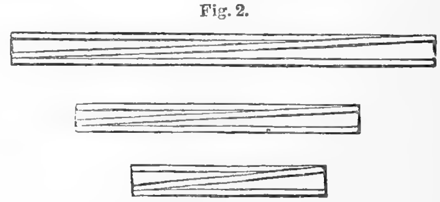
"The velocity of stream was about 188 feet per minute, and the amount of water discharged 1,025 gallons per minute, or 1,476,000 gallons in 24 hours. The gauging of No. 1 section was taken ten feet from the inlet to secure the fair current of water, the pipe being full at the outer end."

In respect to town drainage, the practice of architects and engineers was to enlarge the area of any main pipe in the proportion of the sectional area of each junction into it; whereas it was found by the trial works, that the addition of eight junctions, each of three inches diameter, into a main line of pipe of only four inches diameter, so increased the velocity of the stream, that there was no increase of its sectional area.—(Appendix, No. 2, to Report on Water Supply; Medworth, p. 191.)

Enormous works have been constructed in neglect of these principles, and at more than double cost to the public.

Not only in the quicker flow of the drainage, but a greater fall in an equal length, is obtained by the use of sewers of a small diameter, proportioned to the matter they have to convey. The illustration, fig. 2, will prove this. The large

Fig. 2.



outlines show the size of *level* sewers of large size; by reducing the diameter, a considerable fall is obtained in the same length. This obtaining of a fall is a matter of great importance; the greater the fall, the more quickly will the drainage flow away, and the less deposit will be left in the interior of the drains.

In deciding on the size of sewers, the quantity of house drainage matter is not the only item of consideration; the quantity resulting from "storm water" must also be taken into account. Where this is not attended to, it frequently happens that a sudden and heavy shower will create more water than the drains can carry away; the consequence is, their bursting or blowing up. To meet this exigency, however, drains have been made too large; indeed, its existence has been pleaded as an excuse for the enormous size of the sewers. It appears, however, that the rules, if rules have been at all followed, have not been based upon scientific deduction, but upon haphazard empirical conjectures. The greatest storm which is likely to occur in this country, greater in fact than happens excepting in the course of years, is the fall of two inches in the hour, or 44,789 gallons per acre. Experiments

most carefully conducted have proved that this quantity can be carried away from a space (10 squares of 100 feet) sufficient for three labourers' cottages, by a three inch tube with a fall of 1 in 120; with a fall of 1 in 80, a space (12 square) for one first-rate and four fourth-rate houses; with a fall of 1 in 40, a space (17 squares) sufficient for five fourth-rate houses; with a fall of 1 in 20, a space (25 squares) sufficient for two first-rate and eight fourth-rate houses.

Usually, in calculating the size of sewers for storm water, it is assumed that a certain large proportion of the rain falling upon a town area, will flow into them as quickly as it falls; and that, consequently, they should be made large enough to take that quantity away, supposing it all to enter at the head. Mr. Roe, who has devoted much of his time to this section of engineering, has found that much less of the storm water goes into the drain, in the same time, than is generally supposed, and that sewers receiving along their course the confluence of many smaller channels, will convey away more water than if it all entered at the head.

The following table has been calculated by Mr. Roe, deduced from results obtained from observations extending over a period of twenty years in the Holborn and Finsbury divisions of the metropolitan drainage districts. The table shows the size and inclination of main house drains for given surfaces, and the number of houses of either rate thereon, calculated for a rain-fall of two inches in the hour.

Surface Occupied.		Number of houses, of either rate, either of which may be respectively drained.				Diameter and Inclination of Tubes.								
Acres.	Squares of 100 feet.	1st.	2d.	3d.	4th.	4 inch.	5 inch.	6 inch.	7 inch.	8 inch.	9 inch.	12 inch.	15 inch.	18 inch.
$\frac{1}{4}$	112	2	4	6	9	1 in 120								
$\frac{1}{16}$	195	23	47	10	15	1 in 40								
$\frac{1}{2}$	224	57	84	13	18	1 in 30	1 in 80							
$\frac{6}{10}$	265	5	9	15	21	1 in 20	1 in 60							
1	448	10	15	26	36	......	1 in 20	1 in 60						
$1\frac{1}{4}$	528	11	17	29	40	......	......	1 in 40	1 in 120					
$1\frac{1}{2}$	648	15	23	39	54	......	......	1 in 20	1 in 60	1 in 120				
$1\frac{4}{5}$	814	19	28	49	67	......	......	......	......	1 in 80				
$2\frac{1}{10}$	912	21	32	55	76	......	......	......	......	1 in 60	1 in 120			
$2\frac{1}{2}$	1·094	25	38	65	90	......	......	......	......	......	1 in 80			
$2\frac{3}{4}$	1·200	27	42	71	99	......	......	......	......	......	1 in 60			
$4\frac{1}{2}$	1·970	45	68	117	162	......	......	......	......	......	......	1 in 120		
$5\frac{3}{10}$	2·308	52	79	136	189	......	......	......	......	......	......	1 in 80		
$5\frac{4}{5}$	2·534	59	88	150	208	......	......	......	......	......	......	1 in 60	1 in 240	
$7\frac{4}{5}$	3·432	79	118	205	284	......	......	......	......	......	......	......	1 in 120	
9	3·976	90	135	234	324	......	......	......	......	......	......	......	1 in 80	
10	4 404	101	152	263	364	......	......	......	......	......	......	......	1 in 60	1 in 240

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER VIII.

WITCHCRAFT—THE ONWARD MOVEMENT.

Witchcraft, far more abundant and humbler in its pretensions, was far more tragic in its results. It was supposed to be an agreement or compact between evil spirits and man, whilst in magic the former were compelled to serve the necromancer without any compensation. Magic, though viewed with suspicion by the church, might be practised without a renunciation of Christianity—which was a necessary step in witchcraft. The witches were chiefly ignorant old women, and the powers conferred upon them were chiefly of an injurious nature. They were supposed to excite tempests, to inflict boils, ulcers, and wasting diseases upon man and beast; to blight the crops, summon swarms of noxious vermin, set friends and relatives at variance, &c. On the other hand, they had little or no power of benefiting themselves. They were exceedingly zealous in making converts to their practices. They were supposed to dig up bodies from the grave, and to steal new-born children, in order to make witch-ointments from their blood, fat, and brains. Their aid was often sought to accomplish the death of some powerful enemy. For this purpose an image of wax was made resembling the intended victim, and pierced in various parts with pins, or set up before a fire and gradually melted away. The person represented would, it was supposed, be afflicted with incurable pains in the corresponding parts of his body, or waste away in an unaccountable manner. They also sold amulets or charms for averting sickness; philters or potions for securing the affections of any person of the opposite sex; recipes for becoming invisible;* subtle poisons; and, in short, whatever was requisite for criminal practices. One of their strangest manufactures was the *hand of glory*, greatly in demand among robbers. The hand of an executed criminal was dried with many horrible ceremonies, and a candle of human fat was placed in its grasp. At the touch of the hand, bolts, bars, and locks gave way, and all persons in the house were thrown into a state of unconsciousness.

The witches were supposed capable of travelling through the air mounted on he-goats or on broomsticks, or sitting in a kneading-trough. On certain occasions—usually the 29th of April (Walpurgis' night), and the 31st of October—meetings were held on the tops of high mountains, at which Satan presided. A banquet was served up, which, however, did not satisfy their hunger, whilst the gold which the fiend distributed was found the next morning converted into pebbles or withered leaves. These are significant facts, as far as the explanation of the phenomena is concerned.

Witchcraft early attracted the attention of the ecclesiastical authorities. Its reality was solemnly admitted, the severest penalties—commonly death at the stake—denounced against

* The seed or sporules of the so-called *male fern* gathered in St. John's night was considered powerful for both these purposes—a belief hardly yet extinct in rural districts. See Bamford's *Life of a Radical*, and Shakspeare Henry IV., Act II., Scene I.

its votaries, and special tribunals constituted for its repression. A reign of terror now commenced, measured not by months, but by centuries. To be suspected of witchcraft, or to doubt its reality, was equally dangerous. Accusation was invariably followed by conviction, and conviction by death. What wonder if so convenient a method for getting rid of enemies was greedily embraced; if the philosopher, whose thoughts had outstripped the age—the divine, whose earnestness and purity excited the malice rather than the emulation of his compeers—the merchant or noble, whose wealth seemed a tempting booty—all, in short, who had been unfortunate enough to awaken the prejudices, the envy, or the avarice of their neighbours, were hurried off to the dungeon and the stake as confederates of the devil! The horrors of the first French revolution, so favourite a theme with a certain class of writers, fade into insignificance when compared with the judicial massacres perpetrated under the inducements of a blind superstition. Witch-finding became a regular and a lucrative business. Matthew Hopkins, who flourished during the Commonwealth and in the reign of Charles II., was one of the most notorious and most successful of these informers. The wealthy were often induced to pay large sums of money to escape denunciation, whilst those unwilling or unable thus to gratify the avarice of the informer fell unpitied victims. A work was published in Germany, under the title of the "*Witch-hammer*," or *Malleus mallificarum*, which was soon adopted in most parts of Europe as the mode of procedure against these unhappy beings. Two facts will suffice to show the spirit in which it was conceived. It is laid down that the testimony of criminals and infamous persons may be accepted against the accused, and that an advocate who shows too great zeal in defence of his client becomes thereby an object of suspicion. These horrible scenes were practised in all countries; Protestant and Catholic, Monarchist and Republican, rivalled each other in their blood-thirsty fanaticism. And in order to estimate rightly the condition of these "good old times," these "ages of faith," we must add to the judicial murders a vast amount of private outrage and of moral prostration. Man believed himself the helpless plaything of malevolent spirits; the idea of divine order seemed to vanish from the popular mind, and the actual government of the universe was attributed not to God, but to the devil. We have now to ask, how could this belief in witchcraft take root, and grow to such magnitude? After the official establishment of Christianity, heathenism retained many secret followers. These were in the habit of assembling by night in woods and desert places, to worship the gods of their forefathers. Hence the story of witch-meetings. The witches frequently believed themselves in possession of supernatural power, and declared on their trials that they had flown through the air, and held converse with Satan; that for this purpose it was needful to rub the body with a certain ointment, and pronounce a charm. Now, these ointments are known to have contained ingredients which, like the fumigations of the magicians, powerfully excite and derange the nervous system, producing visions and hallucinations, combined with outward insensibility. The witch, having rubbed her body with this salve, fell asleep, and, her visions being modified by her prevailing ideas, imagined herself borne through the air and mingling in unearthly revelry. The unsatisfactory nature of the banquet (see above), and the disappearance of the gifts received from the fiend, admirably agree with this view. But the decisive fact is, that a witch whom some inquisitors had out of curiosity allowed to try whether she could, by the use of the ointment, escape from prison, fell simply asleep in her cell, yet maintained on awaking that she had travelled through the air in the usual manner.

The belief in witchcraft, and the atrocities therewith connected, yielded by degrees to public intelligence. It is to the growth and spread of physical science that the extinction of this degrading and paralyzing superstition is to be ascribed. The last judicial murder committed in this island on pretence of witchcraft took place in 1720. The statutes intended for its repression have since been repealed—a step which was then denounced as impious and profane. A belief in the existence of witchcraft still lurks in the less cultivated districts, and but a few years ago, a poor old woman was very severely handled by a mob in one of the southern counties. It should be remembered that persons obtaining money by telling fortunes, casting nativities, &c., are liable to imprisonment as swindlers.*

THE ONWARD MOVEMENT.

We have now represented the "decline of learning," commonly so called, the rise of scholasticism, the persecutions of science, the occult systems and superstitions of the middle ages. These considerations have brought us to, or rather among, the epoch of scientific reform—extending from Roger to Francis Bacon, A.D. 1214 to 1620. The two most prominent features of this movement, were the protest against authority, and the appeal to experience. This protest and this appeal were urged with varying success, and with equally varying discretion, by a long series of thinkers. Some were contented with attacking the scholastic peripatetic† doctrine without seeking to erect anything in its room. Others brought forward original systems, little, if at all, superior to those of the past. A third class, lastly, not over-hasty in systematizing, pointed out the necessity of accumulating a store of facts rightly observed. We must, however, guard against the vulgar error of considering this movement a revolution. No new principle was, or could be introduced. Observation and experiment had been practised by the first of the human race. *Now* their value was more fully recognised, and the precautions needed for success were thoroughly investigated. The inductive method had been the type of men's reasoning in the common affairs of life. Whoever had sought to adapt his conduct to circumstances—to seek means for an end desired—to penetrate into the designs of another—had fallen unconsciously into this procedure. *Now* the method was subjected to a searching analysis; from a comparison of its successful with its unsuccessful application, its canons, its fundamental principles were elicited, and the dim "reasoning from experience," common to savage and perhaps to brute, awoke to self-consciousness as the inductive philosophy.

Nor was the protest against authority, a moral rather than an intellectual feature in the movement, altogether novel. If man is naturally inclined to mental bondage, fond of consigning to others the painful task of thought, he is no less tenaciously attached to his own opinion. Like tyranny and slavery in the outer world, dogmatism and servility in the world within are but correlative aspects of one and the same fact. The civilization of the world was now committed to races more tenacious of their individual rights, less ready to merge their personal existence in that of the commonwealth than the Greeks. It was natural, then, that with the spread of mental culture the "right of private judgment" should be claimed and exercised. Whether this right was not and is not grossly exaggerated, might be the object of serious inquiry. That the church had no right to dictate on philosophic matters is almost self-evident; but from the very same consideration it follows, that no man is entitled, without careful study and preparation, to *form*, and much more to promulgate, an opinion on any subject whatever.

Neither was deduction, the favourite method of the Greek philosophers, altogether abandoned, as has been maintained by some superficial writers. Its employment was regulated and limited, and the necessity of a subsequent verification, of testing by fresh observation the accuracy of our results, was strongly advocated.

A variety of outward circumstances powerfully contributed to the changes, or rather to the evolution, now in progress. The advance of the useful arts and manufactures gradually led to the accumulation of a mass of knowledge outside the walls of colleges, and independent of ecclesiastical control; it stimulated man by the prospect of gain, and convinced him of the possibility of a successful interference with the course of nature. The maritime discoveries of the period, the circumnavigation

* Witches were, according to popular belief, detected by laying straws in their path, over which they stumbled. It is a singular fact, that persons under the influence of the narcotics we have just mentioned, see objects so magnified and distorted that a straw appears like a beam or tree trunk, which they attempt to leap or climb over.

† The Aristotelian philosophy, as seen through the smoked glass of injudicious commentators.

of Africa, and the expeditions of Columbus, undertaken in triumphant defiance of the wisdom of antiquity, exercised a similar influence. The discovery of printing, though its consequences have perhaps been overrated, both prevented the loss of any fact once ascertained, and enlisted a larger number of labourers in the cause of science.

Lastly, the capture of Constantinople and the dispersion of the Greek literature had some slight influence upon the career of thought. We are far, however, from ascribing to the "revival of learning," any marked beneficial action upon science. The humanists, the students of classical literature, denounced merely the inelegant language of the scholastics. Further they were unable or unwilling to penetrate. Up to the present day, it is perceived that science and philology mutually exclude each other, that where the latter flourishes the former withers.

Finally, we observe during this period the gradual spread of positivism. The various sciences continue to detach themselves from the old parent philosophy, and assume a definite constitution. Physics makes important progress. Chemistry, emerging from its embryo form—alchemy—is organised, although still under the sway of supernatural conceptions. Physiology is likewise gathering strength. Of the new philosophy, the harmonious co-ordination of all the sciences to one grand whole, we meet only scattered prophecies.

The reformers in general philosophy must first engage our attention. To Roger Bacon we have already alluded as a martyr of science and as an alchemist. This great thinker almost entirely anticipated, in the 13th century, the doctrines promulgated by his namesake in a more favourable era. If we look to immediate results, we must pronounce him unsuccessful; but his teachings gradually spread among the select few, until the time for their public recognition was at hand.*

Next comes Raymond Lully, already known to us as an alchemist. In addition to the various pursuits and enterprises of this remarkable man, he undertook a reform of logic and of philosophy. The want of such a reform was powerfully felt. The logic of the schools was more adapted for discussion than for discovery; it was critical, rather than constructive. A system, therefore, like the *Ars Magna* of Lully, which was at once a new process of reasoning and an artificial memory, found in many quarters a favourable reception. He attempts to re-establish philosophy without any appeal to theology, wishing that reason, instead of being chained to faith, should set out from doubt, seeking to *know*, not to believe. As the object of philosophy, he proposed universal science, a single body of doctrines embracing all principles and all facts. He protested against the one-sided cultivation of reason peculiar to scholasticism, and insisted on the cultivation of the memory, because it is memory alone which furnishes the understanding with positive data. Lully's method consisted of two parts—the former teaching the procedures by which we invent, arrange, and systematise, whilst the latter embraces the objects themselves. All existing knowledge was curiously tabulated by means of a series of moveable concentric circles: two indicating subjects, three attributes, and the outer, all possible questions, namely, whether? what? whence? why? how great? how circumstanced? when? where? and how? The inmost contains the nine essential categories of beings; the second, the nine attributes of physical matter; the third, the nine accidents of moral being; the fourth and fifth, the relative and absolute attributes of beings, whether physical or metaphysical. The absolute are arranged under three heads—essence, unity, and perfection; whilst the relative are grouped under definition, division, and reunion. By combining with the subjects these attributes in various manners, propositions and axioms were framed. Lullism was, therefore, a universal *apperçu*, a panorama of science, a means to familiarise novices with the play of categories, the points of view under which we necessarily consider the objects presented to our senses and to our understanding. It was a resource to aid barren or tardy minds to discover the terms of a chain of reasoning, the mutual bearings of different judgments, the transitions which unite the parts of a discourse, and the materials for extemporaneous discussion. The conception of the enterprise is, doubtless, grand and just. Thought manifestly follows certain laws, and its movements are executed with geometric precision. But the execution was almost ludicrous. We have heard of a "Calmuc praying by machinery," of Babbage's calculating engine, and of an application of the Jacquard loom, adapted to save much labour to those who deem Latin prosody the sum and substance of education; but to argue, to invent, to discover, by setting paper circles in rotation, has an air of the highest absurdity. The Lullian combinations are too arbitrary; the definitions turn in a vicious circle. Above all, how far soever this system might be improved, it is merely verbal, not real. It is tainted with the antique error of supposing that we can obtain a knowledge of *things* by operating with their *names*. It was said that Lullism "confounded distinct principles, abused the facility of generalisation, established an inexact order in its classifications, was deprived of connection and clearness, taught to reason without study or reflection, procuring a borrowed knowledge and a superficial discernment." Lullism underwent a further development in the hands of Bruno.

In the fifteenth century we notice a movement unfruitful in itself, but which may, by unsettling the public mind, have contributed to break down prejudice. Hermolaus Barbarus and others came forward to blame, not the subjects and methods of scholasticism, but its crude style, its imperfect Latinity! This childish preference of sound to sense, of surface to substance, was, as might be expected, accompanied by a morbid admiration of Cicero.

Nicholas of Cusa, or Nicholas Chrypffs (A.D. 1401—1464), was led, partly by his Platonic leanings, and partly by his profound mathematical knowledge, to dissent from the Aristotelian system. He sought the source of knowledge, not in experience, but in conjectures, supposing that the thoughts of the human mind must have a resemblance to real existences. He asserted the rotation of the earth and the fixity of the sun, without, however, carrying out this system in detail, or attempting its demonstration.

Marcilius Ficinus, who died A.D. 1464, and John Picus of Mirandola (A.D. 1463—1494), opposed Aristotle, but with the retrograde hope of re-establishing Platonism. The latter cultivated also the mystical doctrines of the Cabbala.

Patricius, or Patrizzi, whose works appeared in 1593, was likewise a mystical Platonist. His *Nova de Universis Philosophia* promises to establish science on new and indisputable principles. He, had, however, no clear insight into the value and functions of experiment, and his "new principles" are utterly barren. All operations of nature are referred to light as a general cause. His amount of information was, for the age, highly creditable. He protested against astrology, criticised the astronomical discoveries of Copernicus, Tycho, and Fracastori. He instituted many observations on light, the phenomena of tides, the sex of plants, and other subjects in physics, meteorology, and natural history.

A higher rank is due to Bernardino Telesio, the predecessor, in some sort, of the younger Bacon. This illustrious reformer was born A.D. 1508, at Cosenza, in the kingdom of Naples.* He studied first at Milan, then at Rome, and lastly at Padua, devoting himself to mathematics and philosophy with zeal and success. Like so many leading spirits of the age, he became profoundly dissatisfied with the Aristotelian doctrines. This

* Plan of Bacon's *Opus Magus*:—

Part I. On the four causes of human ignorance:—Authority, custom, popular opinion, and the pride of supposed knowledge.
II. On the source of perfect wisdom in the scriptures.
III. On the usefulness of grammar.
IV. On the usefulness of mathematics.
1. The necessity of mathematics in human things. 2. The necessity of mathematics in divine things. Geography, chronology, cycles, the golden number, &c.; natural phenomena, as the rainbow, arithmetic, music. 3. The necessity of mathematics in ecclesiastical things: the certification of faith; the correction of the calendar. 4. The necessity of mathematics in the state; climates, hydrography, geography, astrology.
V. On perspective. 1. Organs of vision. 2. Vision in right lines. 3. Vision reflected and refracted. 4. Propagation of heat and light.
VI. On experimental science.

* Naples, now the Pariah of nations, sodden in apathy, in sensuality, and bigotry, and trodden down under the brutal hoof of a Bomba, was once the very garden of genius. The antique spirit of Magna Græcia breathed in its thinkers, who astonished the world by their brilliant imagination, their truly Ionic subtilty, their almost intuitive perception of the hidden analogies of nature. And in our days—!

view he laid before the world in a work, entitled "*De Rerum Natura*," Rome, A.D. 1565. He subsequently taught philosophy at Naples, where he founded the Cosentine Academy, at one time the first literary institution in the world.* Wearied by the persecutions of the monks, he retired to Cosenza, where he died in 1588. Telesio was more fortunate in the destruction of errors than in the establishment of new truths.† His critique of the peripatetic system is masterly and comprehensive. He clearly feels and proclaims, that a true philosophy must depend upon observation and experiment. "They who before us," he writes, "have inquired into the structure of the world and of its contents, seem truly to have carried on their researches with great zeal, but never to have looked at it." He declares his intention of showing "that the structure of the world, the bulk and properties of the things therein, are not to be investigated by reasoning, as did the ancients, but are to be laid hold of by the senses, and collected from the things themselves." He falls short, however, in practice, as did Aristotle, of his own method. Too often, instead of supporting his propositions by experiment, he appeals to *à priori* reasoning. So long was it before man could learn to renounce his own speculations, and sit in patient humility at the feet of Nature. He errs, too, in attempting to establish at once a complete system in place of the one found worthless. Philosophies do not spring into the world mature, crowned and armed like Pallas out of the head of Zeus. They are the work, not of individuals, but of generations. Tilesio admits three principles: Matter, as a general substratum, acted on by two antagonistic forces, Heat and Cold. With these he plays, it must be confessed, very much in the style of the schoolmen, and accounts for the operations of the universe in a specious but fruitless manner.

Telesio may be regarded as the founder of a philosophic dynasty,‡ whose line was closed, and whose task was finished by Francis Bacon.§ Calabria, noted in our days for brigands merely, produced a man to carry on the great work. Thomas Campanella was born in the year 1568, at Stilo. He early showed, as the gossips phrase it, "proofs of extraordinary talent." He studied at Cosenza, and imbibed there the ideas of Telesio. He has left us an interesting account of his mental career:—"Being afraid that not genuine truth, but falsehood in the place of truth, was the tenant of the peripatetic school, I examined all the Greek, Latin, and Arabic commentators of Aristotle, and hesitated more and more, as I sought to learn whether what they have said were also to be read in the world itself, which I had been taught by learned men was the living book of God. And as my doctors could not satisfy my scruples, I resolved to read all the books of Plato, Pliny, Galen, the Stoics, and the Democriteans, and especially those of Telesio, and to compare them with that first and original writing—the world—that thus, from the primary autograph, I might learn if the copies contained anything false." "When I held my public disputation at Cosenza, and, yet more, when I conversed in private with my brethren of the monastery, I found little satisfaction in their answers; but Telesio delighted me from his freedom in philosophising, and because he rested upon the nature of things, and not upon the assertions of men."

In these lines the reformer, the innovator, is shown most plainly. And when, in 1590, a writer of the old school, one Marta, an authorised and steady-going professor at Naples, published in condemnation of the Telesian system, Campanella, then only in his twenty-second year, boldly replied. His work bears a longer title than would be tolerated in this railway age: "Thomas Campanella's Philosophy demonstrated to the senses, against those who have philosophised in an arbitrary and dogmatical manner, not taking Nature for their guide; wherein the errors of Aristotle and his followers are refuted from their own assertions and the laws of nature; and all the imaginations feigned in the place of nature by the Peripatetics are altogether rejected; with a true defence of Bernardine Telesio of Cosenza, the greatest of philosophers; confirmed by the opinions of the ancients here elucidated and defended, those especially of the Platonists."

Truly, Bacon and Descartes are not far distant. In words like these we feel the breeze of morning!

This work, and others of a similar strain, won for the author the patronage of some, such as the Marchese Lavelli, and the enmity of the monks, the Spanish Government, and the lovers of darkness in general. He was in consequence arrested on a mixed charge of pantheism, rebellion, and scientific reform, and was subjected to fearful barbarities. During forty hours he bore the torments of the rack with more than Spartan fortitude. During the twenty-seven years of his captivity, he wrote consolatory letters to his friends, and even composed a poem on liberty in irons—the sublime and invincible liberty of the soul. Liberated at length by the interposition of Pope Urban VIII., he escaped to Paris, where he lived secure and respected, and died in 1639.

His object was the general reform of philosophy; he sought unity, and wished to organize all truth. He divides science into divine and human. As the *source* of knowledge he indicates experience, and as its ultimate *aim*, the infinite—a manifest inconsistency. In opposition to the scholastics, who set out from definitions, he observes:—"We begin to reason from sensible objects, and definition is the end and epilogue of science. It is not the beginning of our learning, but only of our teaching." His labours were of a highly varied character. A tragedy, which he wrote on the misfortunes of Mary Stuart, is still extant. He must be regarded as a forerunner of *sociology*, the science not yet definitely constituted, which treats of human society and its natural laws. His *City of the Sun*, like the *Republic* of Plato, the *New Atlantis* of Bacon, and the *Utopia* of More, depicts the laws and institutions of an ideal community. Altogether, he must be considered as one of the most advanced, the most positive thinkers of the time, whilst, in his enthusiasm for science, his clear perception of the unity of all truth, and his heroic defence of the liberty of thought, he remains a noble example for us and for all coming ages.

We cannot avoid noticing the economist, Antonio Serra of Cosenza, the contemporary and friend of Campanella, the prophet of free trade.

* The Italian academies (as scientific societies were then styled, the word not having been as yet profaned by misapplication to boarding-schools and other places of rudimentary education) rendered the greatest service both to literature and science. The utility of similar bodies in our own times is becoming somewhat doubtful, since the investigator of nature possesses in the scientific journals, more commodious methods of communicating his results. The general languor of such societies, national or local, proves at least that they do not meet any generally felt requirement of the age.

† Professor Whewell, among the "causes of progress," enumerates the "revival of Greek and Roman literature" and the "Protestant Reformation." Our reasons for denying any high efficacy to the former of these alleged causes we have already stated. The Protestant Reformation had certainly one feature in common with the scientific reform, namely, the protest against authority; and might, by weakening ecclesiastical authority, indirectly promote philosophic research. To rank the religious movement as a *cause* will appear hazardous, if we reflect that the scholastic-peripatetic doctrines were perseveringly maintained in Protestant colleges. It is false reasoning to assert, that because science had been persecuted by Catholicism, it must necessarily be favoured by Protestantism.

‡ He who promulgates a complete though erroneous system, is always more successful in forming a philosophic school, than the more circumspect thinker who merely sows the seeds of great ideas. The former bequeaths to the world a faith to adopt—the latter, a task to execute.

§ The high regard in which Telesio was held by Bacon, who proclaims him "the first of modern philosophers," will justify us in classing the learned chancellor among the disciples of the worthy old Cosenzan. He was, however, no blind disciple, but saw and profited by the failings of his master.

ON THE ACTION OF SEA-WATER ON IRON.

The following is an extract from a letter addressed by Dr. Faraday to the Harbours of Refuge Commissioners, on the corrosion of iron in sea-water:—

"Between cast-iron and sea-water there is a vigorous action; as far as I have been able to observe, it is greatest in the water near the surface, less in deep water, and least of all where the iron is buried in sand, or earth, or building matters (into which the water may penetrate); for then the oxide and other results formed are detained more or less, and form, sometimes, a cement to the surrounding matter, and always a partial protection. Soft cast-iron, as far as my experience goes (which is not much), corrodes more rapidly than hard cast; and the soft, gray, and mottled iron, more rapidly than the brittle white iron. As to the amount of corrosion in any given time, I have not had the opportunity of observing any good and satisfactory cases of illustration.

"In estuaries and the mouths of rivers, it is very probable that

great differences of corrosion will arise from the different circumstances of variable softness, the soil of the river, if near a town, the matters brought down by the waters, &c. &c. The association of iron also with other substances, if metallic, will much affect it; thus a wharf of cast-iron might occasionally be greatly injured by making fast to it vessels that are coppered, using iron cables.

"As to the protection of iron, and first by a coating; the permanency of a coat of paint, or of tar, or bituminous matter, can only be ascertained by reference to experience, of this I have none; except that in a case where coated iron sheathing for ships was brought to me, I was much impressed with the very thorough adhesion of the coat to the iron; the process was patent, and I cannot remember whose it was. Zinced iron would no doubt resist the action of sea-water as long as the surface was covered by zinc, or even when partially denuded of that metal; but zinc dissolves rapidly in sea-water, and after it is gone the iron would follow.

"As to voltaic protection, it has often struck me that the cast-iron piles proposed for lighthouses or beacons might be protected by zinc, in the same manner as Davy proposed to protect copper by iron; but there is no doubt the corrosion of the zinc would be very rapid. If found not too expensive, the object would be to apply the zinc protectors in a place where they could be examined often, and replaced when rendered ineffective; in this manner I have little doubt that iron could be protected in sea-water. It is even probable that, by investigation and trial, different sorts of iron might be easily distinguished and prepared, one of which should protect the other; thus soft cast-iron would probably protect hard cast-iron; and then it would be easy to place the protecting masses where they could be removed when required.

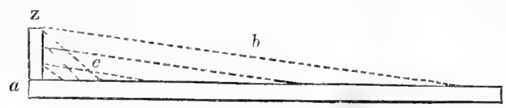
"Hence, though iron be a body very subject to the action of sea-water, it does not seem unlikely that it might be used with advantage in marine constructions intended to be permanent, especially if the joint effects of preserving coats and voltaic protectors were applied. Perhaps engineers are in possession of practical and experimental data sufficient to allow of the formation of a safe judgment on this point; for my own part I am not, and therefore am constrained to express the above opinions with much doubt and reserve."

It must be admitted that the preceding letter is characteristic of the cautious, straightforward writer who penned it, and shows how little is really known concerning the subject of it. A minute and accurate knowledge of the influence of sea-water on iron would be of great importance to the country; but this will never be attained without a lengthened and careful investigation. We do not now allude to a course of chemical analysis merely, but also to a minute and systematic inquiry into all the circumstances which influence the quality of iron in the course of its manufacture: its purity, for example, the mode of casting, the matrix in which it is cast, and its rapidity of cooling. These, and a variety of other circumstances, must be fully observed and classified before we can venture upon the extensive substitution of iron for wood in the construction of harbours or other works where the material is continually in contact with sea-water. Mr. Faraday observes, in the letter above transcribed, that 'soft cast-iron corrodes more rapidly than hard-cast, and soft gray and mottled iron more rapidly than the brittle white iron.' In connection with this remark, we may notice a fact in the cooling and hardening of cast-iron, which is taken advantage of in the casting of ploughshares. If a piece be cast in an iron mould, slightly heated previously, the whole surface of the casting, to a depth of about a quarter of an inch, is as hard as tempered steel, and even closer in texture. The surface portion contrasts also with the interior in texture and hardness, and its superior power of resisting corrosion; it possesses a close and radiated fibrous crystalline structure, while that of the interior is loose, softer, and granular. These distinctive characteristics are no doubt due to the greater rapidity of cooling at the surface, as analogous appearances present themselves in other metals under the same circumstances. From these observations there is no doubt of the superiority of hard cast-iron to the soft for marine purposes; and it suggests the propriety of casting iron for such purposes in metallic moulds.

In connection with the professor's suggestion in another part of his letter, as to the voltaic protection of the cast-iron piles proposed for lighthouses, &c., by zinc, we shall offer a few remarks from our own experience. Every two metals have a negative and positive tendency in connection with one another, when in contact with a fluid; and the nature of the fluid materially influences these negative and positive tendencies. The following is the order of the metals enumerated in connection with sea-water:—Silver, copper, bismuth, tin, lead, cobalt, nickel, iron, cadmium, zinc; the first the most negative, the last the most positive in the scale, so that the further apart in the scale the two metals selected for experiment may be, the more decided is their relative negative and positive tendency. Copper and zinc, for instance, operate more strongly together than iron and zinc. These tendencies may be accounted for thus:—A metal that is insoluble when placed singly in a fluid, may be made soluble by connection with a relatively negative metal in the same fluid. For example, pure zinc remains unaffected in sulphuric acid; but, when connected with copper in the same solvent, it is powerfully operated upon. A single metal that is soluble in a fluid, may be rendered insoluble by connection with a relatively positive metal, which undergoes decomposition in its stead. Thus copper is dissolved by sea-water, when unprotected; but if protected with zinc, it remains unaffected. This is the substance of Davy's method of protection alluded to by Dr. Faraday; and, in applying the principle, it is necessary to take into consideration, first, the amount and power of electricity generated by the connected metals in the same fluid; and, secondly, the conducting power of the metal being protected.

First, the amount and power of the electricity evolved is in proportion to the difference of the relative negative and positive conditions of the metals employed. Now, the more positive the protected metal, the more liable it is to be destroyed, and the greater evolution of electricity would be required to protect it. Suppose, for example, 4 square inches of zinc in connection with 4 square feet of copper, is sufficient to protect it, with the evolution of a certain amount of electricity; there would be required 2 square feet of zinc in connection with 4 square feet of iron to yield an equal amount of electricity;* still, the same amount of electricity, or even double that amount, would be insufficient for the protection of the iron from sea-water, as iron is so much more positive than copper.

Secondly, the conducting power of the negative or protected metal, subjected to submarine immersion, is a circumstance of very great importance. If a piece of copper and a piece of zinc be connected under a solution, say a copper bar, C, four feet long, with a piece of zinc, Z, four inches in length, erected on one end, as in the annexed sketch; the conducting power of the copper is so much superior to that of the



solution, that the whole length of the bar will become instantaneously negative, and the current will pass to and from all parts of the bar at the same time, in the lines *b*, *b*, though it will do more so towards the point of contact than towards the distant extremities, the resistance of the liquid offering less obstruction towards the point of junction. If, again, a bar of iron, and a piece of zinc as a protector, be placed in the same circumstances, the phenomenon assumes quite a different aspect: the conducting power of iron is much less than that of copper, so much so, that the distant extremity will not be affected by the electric current; the latter will find a short passage at the dotted lines, *c*, beyond which the electric effect ceases. Even in that segment of the bar which is under the influence of the current, the more proximate portions are better defended than those which are farther distant. This circumstance of partial protection, while it induces a negative state at the near end, renders the other end more positive; such a diversity of condition gives rise to voltaic action between the two extremities of the bar, and the result is the destruction of the far end at the expense of the other. In all cases of voltaic protection, the more equal the influence over the whole surface protected, the more perfect is the protection. An inequality of protection such as we have already illustrated, is productive of numerous evils. It is, we believe, the source of many of the injuries occurring in our day to copper-sheathing; one part of a sheet becoming, by some local cause, negative, the other parts are rendered positive, and the result is, that the borders of an individual sheet either overlapping or underlapping its neighbouring sheet, an electric current is excited, passing through the stratum of moisture that may intervene, and the ultimate effect is, that the positive edge is dissolved as evenly as if cut by a knife. The evil arising at one place may be contagious, and affect a whole neighbourhood.

In the protection of iron by voltaic means, it is necessary that the zinc be at least as extensive as the iron; and even then the protection is incomplete, though the destruction of the iron is of course much retarded. In sea-water, zinc of any dimensions is a very partial protector of iron. Even a bar of iron placed in a zinc vessel filled with sea-water, is not completely protected. In fresh water also, zinc is only partially effective, even when it is applied as a coating to the surface of the protected body; for it speedily passes into a blackish substance, probably containing oxygen, sulphur, and iron, which peels off and exposes the iron to rust. When the iron is simply exposed

* These proportions are given in round numbers, though they vary according to the kind of iron, the state of the water, the distance of the metals. &c.

to the air, a good coating of zinc is the only sure protection. We have in our possession specimens of iron of various qualities coated with zinc by the electro process, which have been for the last three years exposed to all weathers; some of them are yet unaffected, excepting the change in the colour of the zinc to a dark grey; where abrasion has taken place in the others, the galvanic influence is nothing, and the iron rusts as if there were no zinc present. This is no more than what might have been anticipated, as there can be no electric excitation without a liquid to connect the two metals.

It is hoped these cursory remarks will induce some of your readers to become close observers in this interesting department of practical science, with respect to all the circumstances which operate in protecting or destroying metals. In regard to iron in particular, every moulder and mechanic has a variety of opportunities within his reach of making investigations of the kind we have been discussing. And were every one to contribute his quota of observations, however limited, if they were accurate, to the public stock—and his facilities for doing so are abundant—there would be amassed, in the course of a few years, such a stock of data as would not fail to afford other views of the nature and properties of iron than those which are at present entertained.

THE MANUFACTURE OF GAS.

CHAPTER I.

COAL GAS.

It is well known that the word Gas was first introduced into chemistry by Van Helmont, in his "Treatise de Flatibus." Junker, whose "Conspectus Chemio Theoretico Practicæ" was published in 1744, conjectures that Van Helmont's word gas, was merely the German word *gascht* (fermentation) in a Latin dress, and this conjecture seems as probable as any.

Boyle was the first chemist who attempted to make gas artificially, and who showed that thus prepared it possessed the mechanical properties of common air. The gas which he examined was hydrogen, obtained by pouring dilute sulphuric acid on iron filings.

Hales, in 1726, proved by experiment, that many animal and vegetable substances, when heated sufficiently, give out an air which possesses the mechanical properties of common air, and which, therefore, he considered as not differing in its properties from common air. That hydrogen gas was combustible, was known at least as early as the beginning of the last century; and many remarkable stories are told by early chemists of the eighteenth century about its combustibility, and the violent explosions which a mixture of it and common air produced when brought in contact with a burning body.

Dr. Black first showed that carbonic acid, though a gas, differed essentially from common air, and he gave it the name of *fixed air*, because it existed in a solid state in the carbonates. Cavendish, in 1766, showed that hydrogen differs from common air and from carbonic acid. He examined its combustibility, its specific gravity, and its peculiarities. In 1772, Dr. Priestley began his experiments on air. First he examined carbonic acid and hydrogen; then azotic gas, then deutoxide of azote, muriatic acid gas, and ammoniacal gas. In 1774, he discovered sulphurous acid gas and oxygen gas, which was destined to make such an alteration in the chemical theories of the time. He discovered fluoric acid gas and carbonic oxide, though he was not aware of its peculiar nature, and, indeed, remained ignorant of it to the end of his life.

It is curious that Dr. Priestley nowhere, so far as I know, mentions carburetted hydrogen, or heavy inflammable air, as it was then called. It constitutes the *fire damp* of coal mines. Its combustibility, and its property of exploding with great violence in certain circumstances, must have been known in coal countries at a pretty early period. In the Philosophical Transactions for 1667, there is an account of a blower of this gas passing through and taking fire from the flame of a candle, and burning briskly; and in the same work there are many histories of explosions in coal mines, attended with the loss of many lives.

Though carburetted hydrogen occurs so commonly in coal mines, and though it burns with a strong flame and gives out a good deal of light, and although it had been ascertained that when common coal was distilled at a red heat it gave out a great deal of inflammable gas—it does not seem to have occurred to any person to employ it as a substitute for candles, till the idea struck Mr. Murdoch, an Ayrshire gentleman in the employ of Watt & Boulton. In the year 1808, he published a paper in the Philosophical Transactions, pointing out the advantages that would result from employing coal gas instead of oil for illuminating the streets of towns and manufactories.

In this paper he gives an account of the apparatus which he had fitted up for lighting the cotton manufactory of Messrs. Phillips & Lee at Manchester, which was at that time the greatest cotton mill in the kingdom. He shows that the expense was only about one-fourth of that of the candles or oil necessary to produce the same quantity of light that the gas did. The coal used was the best Wigan cannel, a ton of which, he says, yields 7160 cubic feet of gas, and produces about two-thirds of a ton of coke.

In this interesting paper, Mr. Murdoch gives the history of the discovery of gas-making. In the year 1792, while at Redruth in Cornwall, he made a set of experiments on the quantity and qualities of the gases produced by distillation from different mineral and vegetable substances. He was induced, by some observations which he had previously made on the burning of coal, to try the combustible properties of the gases produced from it, as well as from peat, wood, and other inflammable substances; and being struck with the great quantities of gas which they afforded, as well as with the brilliancy of the light, and the facility of its production, he instituted several experiments, with a view of ascertaining the cost at which it might be obtained, compared with that of an equal quantity of light yielded by oils or tallow.

In the year 1798, he removed from Cornwall to Boulton & Watt's works at Soho, and there he constructed an apparatus upon a larger scale, which, during many successive nights, was applied to the lighting of their principal building, and various new modes were tried for washing and purifying the gas. These experiments were continued, with some interruptions, till the peace of 1802, when a public display of the gas light was made by him in the illumination of the manufactory at Soho on that occasion.

Since that period, or between it and 1808, he extended the apparatus at Soho, so as to give light to all the principal shops, where it was in regular use, to the exclusion of other artificial light. In 1808, he fitted up the gas apparatus in Messrs. Phillips & Lee's cotton mill; since which time it has been extended to all the cotton mills in the kingdom.

I have stated these details, though but imperfectly connected with the subject which I mean to discuss, because I believe the history of the introduction of gas as a substitute for oil or candles is not very generally known. It is generally ascribed to Mr. Windsor, who took out a patent in 1806, and who delivered lectures on the subject several years after, and who endeavoured to get up a joint-stock company, with what success I do not know. Several attempts were made in Glasgow about the year 1808, and during the winter of that year the front of the Tontine buildings at the Cross was lighted with gas for several weeks. London was the first city illuminated with gas. Philip Taylor erected the gas works at Paris soon after the peace of 1815.

In the preceding historical sketch, I have taken no notice of Lord Dundonald's coal-tar works at Culross. The current of gas escaping from his ovens was frequently fired; but it does not seem to have occurred to him to employ the gas thus extricated for economical purposes. Nor have I noticed M. Lebon, who is said, in 1786, to have attempted, but without success, to employ gas distilled from wood as a substitute for candles. These attempts led to no results, and were speedily forgotten.

The preceding historical facts are given from a paper which was read at the Glasgow Philosophical Society many years ago, by the late distinguished Dr. Thomas Thomson, Regius Professor of Chemistry in the University of Glasgow. The reading of this paper was followed by an interesting discus-

sion, during which the following observations were made by Mr. John Hart:—

Having heard that Lord Dundonald used gas from coal as a light, long before Mr. Murdoch's discovery, and being in Culross Abbey while it was unroofed and in a state of ruin, I naturally began to examine the walls, to see if I could discover any trace of the pipes, when Sir Robert Preston's gardener informed me that he believed no pipes were used, as some of the old people of Culross who saw it, told him that the gas was carried in a vessel from the tar-works and burned in the Abbey.

I afterwards discovered that an intelligent old man, a blacksmith in our neighbourhood, had been long in the employment of his lordship, and that he had been his assistant in many of his experiments about that period; from him I received the following account:—His lordship having been in company with some scientific friends, on the following morning he mentioned to his blacksmith, that, on the previous night, he had been shown a work [probably Dr. Richard Watson's Chemical Essays] which gave an account of a process for distilling pit coal, and from which a substance like tar might be obtained in considerable quantities. This he wished to try, as he thought it might be made to serve the purposes of common tar; and he then told him to come along with him to the garden, where he pointed out a spot, and gave him instructions to set about the erection of an oven or kiln to try it; the experiment succeeding, nothing more was done until it was secured by a patent. Soon after, nine cylindrical ovens of brick were built in a row, along a bank of earth; these were about 3 feet in width and about 7 feet deep, being hemispherical at top and bottom, each having a moveable cover at top for charging, and a well-fitted door at bottom to regulate the combustion: a 7-inch cast-iron pipe near the top conveyed the products to the condenser on the top of the bank. The condenser was a flat box of lead, having divisions partly crossing it to detain the vapours of the tar, and very much resembled the coolers used by brewers, from having a rim to retain cold water on its upper surface, with which it was plentifully supplied. The tar was conducted by a pipe into similar cylinders of brick-work on the opposite side of the bank; each of these had a small opening in the top for the escape of the incondensable part of the products. To these openings the workmen were in the habit of attaching a cast-iron pipe by means of a lump of soft clay, and lighting the gas at the other end to give them light during the darkness. His lordship also was in the habit of burning the gas in the Abbey as a curiosity; and for this purpose, he had a vessel constructed resembling a large tea urn; this he frequently caused to be filled and carried up to the Abbey to light the hall with, especially when he had company with him. On one occasion, after a fresh charge, the workman having applied his light too soon, an explosion took place, which nearly killed some of the men and tore off the top of the condenser, and one of the workmen's wives passing near it at the time was blown off the bank; fortunately she fell over into her husband's lap (who happened to be sitting below at his breakfast) without receiving any other injury than the fright. However, after this accident, the men became very cautious in applying a light to the pipe until the whole of the atmospheric air was displaced. In giving this statement, I do not mean to detract in the smallest degree from the merits of Mr. Murdoch, as it appears that this gentleman knew nothing of what was going on at Culross: all I wish to show, is the state of knowledge on this subject in Scotland ten or twelve years prior to Mr. Murdoch's discoveries.

What Dr. Arnott says of the water-pipes of London, ramifying through every street, and lane, and alley, and distributing their valuable contents to the dwellings of its inhabitants, we may to a certain extent say of the pipes through which our supply of gas is obtained.

"The supply and distribution of water in a large city, since the steam-engine was added to the apparatus, approaches closely to the perfection of Nature's own work in the circulation of blood through the animal body. From a general reservoir a few main pipes issue to the chief divisions of the town; these send suitable branches to every street, and the branches again divide for the lanes and alleys; while at last into every house a small leaden conduit rises, and, if required, carries its precious freight into every apartment, where it yields it to the turning of a cock." The analogy is true so far as regards the emanation from a centre, the branching out of minor pipes from those of larger diameter, the lateral small pipes leading into the houses, and the concealment of the whole assemblage beneath the pavement and roadway; but the subsequent movement from the branches back again to the centre, though observable in the flow of water through drains into the rivers and seas, the evaporation from thence, and the feeding anew the springs from which the supply was originally obtained, is not so observable in the gas circulation.

Be the analogy what it may, however, no thinking person can fail to be struck with the admirable means whereby our cities and towns are now lighted. So far back as the year 1823, when gas companies were comparatively in their infancy, a Committee of the House of Commons spoke highly of the system of lighting streets by gas, as a measure of street police; and there can be no question that the doers of evil, who "love darkness rather than light," infest the streets of London not only relatively, but positively less now than before the introduction of gas, although the inhabitants have increased three or four hundred thousand in number. The beauty and convenience of the light afforded by gas in streets, shops, and buildings, are appreciated by all; but the protection which it gives, though not so fully understood, is not less worthy of notice.

It will be convenient at once to enumerate, before describing the arrangements of gas-works, the successive steps or stages in the process. 1st. The carburetted hydrogen, which constitutes the gas for illumination, is one of the ingredients in common coal, and is separated from it by distilling the coal in highly heated vessels secluded from the access of the air. 2d. The substance left behind in the heated vessels or retorts, after the volatile portions have separated from it, forms the fuel known as coke, which is either sold to other parties, or is used with or without admixture with coals to heat the retorts. 3rd. The volatilised ingredients are so far from being pure carburetted hydrogen, that they comprise tar, ammonia, sulphuretted hydrogen, and other substances, all of which must be removed before the light-producing ingredient will be in its proper degree of purity; and the first part of this purification is effected by a piece of apparatus called a hydraulic main, in which the coarser impurities are deposited. 4th. The gaseous product passes through pipes, which are either immersed in cold water, or are sprinkled by a jet of cold water externally; whereby all the impurities which are in the gaseous form only at high temperatures are condensed, and fall into a vessel beneath; hence this process is called condensing. 5th. The remaining gas contains sulphuretted hydrogen, as well as curburetted hydrogen; and in order to remove the former, the whole is agitated in a vessel containing either lime or lime-water, which combines with the deleterious ingredient, and leaves the curburetted hydrogen tolerably pure. 6th. The gas thus made is conveyed through pipes to immense store-vessels, called gasometers or gas-holders, where it is kept out of contact with the atmosphere by inverting the vessel in a tank of water. 7th. The gas passes through a meter or measurer, whereby the whole quantity made throughout a given period, and the rapidity of formation at any particular point of time, are determined. 8th, and lastly. The gas is conveyed from the meter to the various streets and buildings by pipes laid uuderground, the supply being regulated to the demand by gauges and valves placed near the meter.

The establishment of the large gas-works of London was an interprise beset with numerous difficulties. Mr. Winsor, after lecturing on the subject at the beginning of the present century, formed a "National Light and Heat Company," which, though built upon rather fanciful grounds by the projector, became the parent of all the gas companies, and has ever since taken the lead among them. The works were established at Westminster, forming a portion of the present

large station there. Mr. Matthews, who wrote a history of gas-lighting about fifteen years ago, takes the following view of the establishment of Mr. Winsor's company, which had become a chartered body:—"Various and plausible as were the objections urged against it at the time, experience has proved that the property of an individual was neither adequate to the magnitude, nor likely to be risked in such large and expensive undertakings; and this was shown by some facts adduced in the evidence to support the bill. By calculations that were made from actual surveys, it appeared that the expense of laying down pipes for the city of Westminster alone would be one hundred and fifty thousand pounds, without including anything else. There were also other circumstances that entitle this company to particular attention; for, previous to this period, their experiments for making, purifying, and applying the use of coal-gas to the purposes of lighting, had been made on a large and expensive scale. And although the public had been partially benefited from the knowledge obtained by their means, hitherto no pecuniary advantage had resulted to themselves, notwithstanding their zealous exertions to improve and introduce the art of gas-lighting. However, the hope of future benefits animated them in their further efforts to attain their object. Perseverance enabled them to overcome the great difficulties which attended their pursuits; the success of their endeavours has excited and encouraged others to engage in the same course, and imitate their example; and how many similar companies may trace their origin to the stimulus produced by the successful establishment of this!" The buildings which had been erected at the Westminster station before Mr. Matthews wrote, together with those which have been subsequently added, have cost no less a sum than three hundred and fifty thousand pounds.

The following description of one of the great London gas-works will convey a general idea of all. On passing through the entrance-gates, we see on the right hand a range of offices and counting-houses, called collectively the 'Coke Office,' while another range on the left hand is occupied as the 'Light Office.' In these ranges of buildings are the offices for the committee of management, the superintendent, the clerks, and others engaged in counting-house duties. The terms 'coke-office' and 'light-office' relate to the two great departments into which the operations of most or all gas companies are separated; for the sale of the coke produced in the manufacture of gas, though certainly subordinate to that of the gas itself, is an item of great importance, and receives a proportionate share of attention. If coals could be brought to the London market at a price somewhat proportionate to that demanded at the pit's mouth, the sale of coke would not be looked to as a matter of so much importance; but the enormously high price which London manufacturers of every kind, as well as private persons, have to pay for coals, renders it necessary for the gas manufacturer to attend to the production of coke, either for heating the retorts or for sale. The kind of coal employed is selected, not with relation to the absolute quantity of gas which it will yield, but with reference to its yielding both good gas and good coke. In our common domestic fireplaces, we know that one kind of coal will concrete into a mass by a sort of semi-fusion, forming cinder; while another sort will burn away to a white ash without producing cinder. Similar differences exist in the combustion of coal in retorts; and the gas manufacturer for the most part rejects that quality which will burn away to a white ash. One portion of the coke produced at the works is afterwards used in the ovens or furnaces to heat the retorts, and the remainder is sold to manufacturers, dealers, and private persons. The 'coke-office' is the place where all the arrangements connected with the sale of the coke are carried on; while the clerks in the 'light-office' similarly manage the dealings of the company with the gas consumers.

The two offices just named lie at the southern end of a large quadrangle or court, and from them we proceed to the other buildings, turning to the right after passing the entrance-gates. At and adjacent to the south-east corner are four of those bulky vessels which form the most conspicuous objects in a gas factory. The term *gasometer* applied to these vessels is a very inappropriate one, inasmuch as it conveys an idea of measurement as connected with the purpose of the vessel; whereas the gasometer is in truth nothing more than a gas-holder, in which gas may be accumulated and stored. In the earlier history of the manufacture, however, the gas-holder was made to serve the purpose of a gas-measurer, by the addition of a scale of feet and inches, so that the depth of gas in the vessel, multiplied by its area, gave the cubic contents; and thus the term 'gasometer' became introduced. So far as regards the quality and efficacy of the gas, a gasometer might be dispensed with, the gas being conveyed at once from the purifiers to the mains and burners; but it would be impossible thus to regulate the supply to the varying demand. As a shopkeeper provides a store of goods more than sufficient for immediate demand, in order that he may be prepared for future fluctuations, so must the gas-works accumulate during the daytime a quantity of gas adequate to the enormous and sudden demand which occurs about dusk. From the first establishment of gas-works it was found necessary to provide this reserve store, but it was hoped that some means would be discovered of dispensing with the bulky gasometers. Such means have, however, not been found, and all the gas-works exhibit these capacious reservoirs. Persons to whom the arrangement of gas apparatus is not familiar, are often surprised at the different appearances which a gasometer, as seen towering above the wall of a gas-factory, presents at different times. At one period a kind of scaffolding of light and elegant iron-work is seen, forming a triangular space, within which an enormous cylinder stands at a small height from the ground; at another time, perhaps, after an interval of a few hours, the cylinder will be seen to have ascended ten or twelve feet; and at a subsequent period to have ascended nearly to the top of the framework, forty or fifty feet in height. These differences may be easily understood, if it be borne in mind that a gasometer consists in reality of two vessels, one within another, the outer one being a tank open at the top and closed at the bottom, and the inner one being an inverted vessel open at bottom and closed at the top. The tank is filled to a certain height with water, into which the inverted vessel dips, so that the interior of the latter is cut off from communication with the external air by the interposition of the water. A pipe passes into the tank quite through the water, and terminates in the vacant space within the cylinder; and through this pipe the gas, when completely made and purified, is conducted. Now, as carburetted hydrogen (common gas) is not half so heavy, *i. e.* has not half the specific gravity of atmospheric air, a certain bulk of it collected in the cylinder gives an ascensive power to the latter, notwithstanding the ponderous character of the metal; and the cylinder rises higher as the quantity of the contained gas increases. Balance-weights are suspended outside the gasometer, to counterbalance in a certain degree the weight of the iron cylinder; and these weights are so adjusted as to give to the gas a pressure or elastic force slightly greater than that of the atmosphere. The reason of a gasometer rising, then, when full, is that the iron gasometer with its included carburetted hydrogen is lighter than an equal bulk of atmospheric air.

The tank of a gasometer is made of cast-iron, while the gas-holder is formed of sheet-iron, the sheets being riveted at the edges, and a piece of string being inserted at every joint, to make it air-tight—a simple but valuable contrivance suggested a few years ago by a workman. In some cases a strip of tarred canvas is inserted at the joints, or else canvas coated with white lead.

The four gasometers described as occupying the south-east corner of the quadrangle, have what is termed the telescope construction, in which there are two gas-holders, one within another, and both within the tank; the inner gas-holder is filled first, and then, by an ingenious contrivance, elevates the outer one as the gas continues to enter; the object being to gain a greater capacity without increasing the diameter of the vessels, since the increased height of the apparatus is not so costly as an increased ground area. The tanks of these

gasometers are about forty feet in diameter and eighteen feet high; and the gas-holders when full reach to a height of nearly forty feet. About twenty years ago there were some strange misconceptions afloat respecting the danger to be apprehended from the explosion of gasometers; but in the report of a committee appointed by the House of Commons to investigate the matter, the following remark set the doubts at rest:—"As long as every part of this reservoir is kept in good repair and perfectly tight, the pipes leading into and out of it maintained in proper condition, and plenty of water supplied, so that the parts which should be under water shall never be left bare, it seems to your committee scarcely possible that any explosion should take place." The experience of subsequent years has shown that the gasometers are perfectly safe, and they are now made of much larger dimensions than any known at that time. The average capacity of the four alluded to above is about forty-five thousand cubic feet each. Some of the gas-works have gasometers very much larger than these.

Between or adjacent to the gasometers are cisterns, whose use curiously illustrates the branches of commerce which arise out of the gas manufacture. We have slightly noticed the separation of a liquid containing the alkali ammonia from the other products of the combustion of coal. This ammoniacal liquor was at first a trouble and a burden to gas manufacturers; but after a time a market was found for it, and it is now regularly purchased by the proprietors of chemical works, as a source whence ammonia, or some of its compounds, may be obtained. The tar, which is another product of the combustion of coal in retorts, and of which more than a hundredweight is produced from a chaldron of coals, is separated from the gas by the same process, and in the same vessels as the ammoniacal liquor, and is in fact mixed with it; but as the tar has greater specific gravity than the ammoniacal liquor, it gradually assumes the lowest place in the vessel, and is then easily separated. Different plans have been adopted at different establishments in appropriating the tar thus produced; some sell it at once, as fast as it is produced; some consume a portion of as fuel in the retort-house; while others, by a process of distillation, separate it into a volatile oil or naphtha, a fixed oil, and a solid residue nearly resembling common pitch.

Northward of the gasometers and the tar and ammonia vessels is a roofed building, called the 'condensing or purifying house,' filled with a complicated series of vessels, employed, first, in condensing all those impurities which are capable of condensation, and, secondly, in purifying or separating the gas from a portion of sulphuretted hydrogen which is always produced with it, and which, besides interfering with the brilliancy of the light, would produce a most disagreeable and unwholesome odour. Condensers of a great variety of forms have been used at different times and in different establishments; but those at the works under consideration consist of a pipe with a number of ascending and descending bends in it, and short pipes at the lower end to allow the tar and ammonia to flow out. A constant stream of cold water is flowing down the outside of each pipe, by which the gas, as it passes through, is cooled, and the condensable impurities separated from it. From the condenser the gas passes to the purifiers, of which there are three complete sets in the purifying-house, each set consisting either of three or four large cast-iron vessels. Without going into minute details, we may just state that the three or four purifiers forming one set are placed side by side, but at different elevations; that each vessel is supplied with lime-water, which is kept constantly stirred by a revolving apparatus within; that the gas passes successively through all the vessels, parting as it goes with its sulphuretted hydrogen, which combines with the lime-water. The lime-water is changed frequently when it becomes too much sulphuretted, and matters are so arranged that one bushel of lime will purify twenty thousand cubic feet of gas. The rotating machinery in the purifying vessels, the working of the pump in the well, and the removal of the tar and ammoniacal liquor from one vessel to another, are effected by steam-power.

The next building to the purifying-house is one in which the sulphuretted lime undergoes certain processes, after being removed from the purifiers. Some of the most important improvements in the gas manufacture relate to this part of the proceedings. The lime-water is conveyed from the purifiers to a large underground cistern, and from thence to a range of cast-iron vessels, in what is termed the 'pug-mill room,' where it is allowed to settle, by which the principal part of the lime subsides and separates from the sulphuretted liquor. The lime is then taken to a 'pug-mill,' a sort of a churn, and there mixed up with clay, to form a cement or 'lute' for securing the covers of the retorts. The liquor is wholly evaporated, or driven off in the form of steam by pouring it into shallow pans occupying the floor of the furnaces or ovens in which the retorts are heated. This mode, so far from being inconvenient, is productive of benefit in another way; for the steam arising from the liquor tends to cool the bars of the furnace, and thus to preserve them.

Next to this building is a carpenter's shop, in which woodwork for various purposes connected with the factory is made and adjusted. Adjoining this is a store-room for firebricks (used in the retort furnaces) and some other articles; and in the open area in front are two large vessels called saturators, through which the whole of the gas passes after leaving the purifiers, and before being conducted to the gasometers. The gas is, by a peculiar arrangement, subjected to a chemical process which gives it a very high degree of purity, by abstracting all the ammonia.

We have now passed along the eastern side of the large quadrangle, the open area of which exhibits much bustle and activity. Here waggons laden with coals, and passing to the coalstores; there waggons and carts belonging to dealers in coke, who have come to purchase; in one place heaps of iron pipes; in another, of retorts, about to be put in the place of old ones; while men are bustling about in all directions. In crossing over to the western side, past the end of the central building, we catch an end glimpse of two of the retort-houses; through a dark arch the eye can just discern the movements of men passing to and fro in front of the retorts, while an occasional gleam from the retorts themselves suddenly lights up the spot.

The western side of this quadrangle is occupied almost entirely by gasometers, enclosed in brick buildings without roofs. A portion of the space is, however, occupied as a coal store, one of the many receptacles for the vast quantity of coals consumed here. A contemplation of such immense supplies of fuel, and of the invaluable services derived therefrom, brings to mind the remark of an elegant writer, that the coal-mines of Britain "are, in effect, mines of labour or power, vastly more precious than the gold and silver mines of Peru, for they may be said to produce abundantly everything which labour and ingenuity can produce, and they have essentially contributed to make her mistress of the industry and commerce of the earth. Britain has become to the civilised world around, nearly what an ordinary town is to the rural district in which it stands, and of this vast and glorious city the mines in question are the coal-cellars." Fears have been entertained by some, that the time must be looked forward to when this precious supply will fail—when the mines, worked at their present enormous rate, will no longer yield their wonted product. But the more investigations are made, the more remote seems to be the time when such a misfortune will befall us; and we may safely leave to future ages the adoption of a remedy, if not a prevention.

There is an inner quadrangle, containing another series of condensing and purifying apparatus, comprising vessels similar to those before described, as well as an ammonia tank, pumps, &c. Beyond these, on the right, is a large smiths' shop, where men are busily engaged in the repair and adjustment of various articles used in different parts of the works. The gasometers, condensers, purifiers, tanks, retorts, mains, pipes, and other iron-work of magnitude, are of course made at the large foundries, but there are abundant demands for smiths' work on a smaller scale at such an establishment as this. The northern end of this smaller court is occupied

principally by one gasometer, the largest in the establishment having a capacity of eighty thousand cubic feet; it is well placed, and has an imposing appearance, especially when raised to a height of fifty or sixty feet. On the left or west side of the court are two of the four retort-houses—iron-roofed buildings—in which the gas is made. The arrangement of these houses we shall speak of presently, and need only say here that these two present the same striking and remarkable features which characterise the other two. In the open court of the quadrangle are indications of the same traffic and bustle which the other presents; the arrival and unloading of cargoes of coal, the heaping and sprinkling of the heated coke, just brought smoking and steaming from the retort-house, &c. At various convenient places in this, as in the other quadrangle, are store-houses for coal, from whence the retorts are supplied; and in addition, wherever room could be found for them, gasometers are placed.

We have now noticed the principal buildings, apparatus, and general arrangements round both quadrangles of the establishment, and will next return to the one first described, and take a hasty glance at the building in its centre. This building is divided into various departments, such as a deputy-superintendent's office, an inspector's office, a meter-room, a valve-room, two retort-houses, a coal-store, a coke-store, an engine-room, &c. The four first-mentioned rooms form a kind of additional building attached to the southern end of the remainder, and with its motto, "*Stet capitolium fulgens*," is the first object which meets the eye from the entrance. The retort-houses are built at a few feet distance from the ground, leaving space beneath for the coal and coke stores.

Whoever enters for the first time into a retort-house, cannot fail to be struck with its appearance, so different from that of most other factories. The iron roof, the iron floor, the absence of windows, the absence of machinery and work benches, the strange appearance of the walls, speckled over with complicated iron-work (whose purpose is not clearly discernible), the darkness of the place, the appearance of the men—all have an aspect of strangeness. But at intervals of every hour or two, and especially at night, the visitor's attention is suddenly awakened to a startling scene going on within the building. He sees a party of men advance to one part of the side apparatus; he sees them turn the handles of what appear to be screws; he hears several explosive reports, followed by the removal of circular iron doors or covers about a foot in diameter; he sees a burst of flame from each hole whence a cover has been removed; and on going in front of one of these openings (if he have courage enough), he will perceive a mass of intensely burning coal or rather coke, extending back to the depth of six or seven feet. Then will follow the removal, by means of rakes, of all the burning materials from each opening; then the hissing and steaming consequent on the wetting of the coke by buckets of water; and then the recharging of the heated cavity with fresh coals. It is not until after noticing this succession of operations, that a stranger can rightly understand the arrangements of such a place. They are—with slight exceptions, which we need not heed here—as follow:—Each side of the retort-house has a succession of arched recesses, each eight or ten feet high, six or seven wide, and about as many in depth. These recesses, when bricked or otherwise closed in front, form ovens or furnaces, in which fuel is burnt on a grate at the lower part. Five, six, eight, or more oblong iron vessels, each holding from two to three bushels of coals, are ranged horizontally in this oven, from front to back, so that the heat, flame, and smoke from the furnace may play around them, and make them red hot. The outer end of these vessels, which are the *retorts* (a name for which we have never heard a good reason assigned), are left open or closed as occasion may require; an iron door, connected with a screw, being accurately fitted to each retort. The retorts are semi-cylindrical in shape, with the flat side placed lowermost. The average height of the retorts is perhaps about five feet from the ground; under them is a fireplace, through which the fuel is introduced by which they are heated; and under this again is a kind of ash-pit or shallow vessel, into which the lime-water is poured for the purpose of evaporation. The operation then consists in this:—The empty retorts are first brought to a red heat; then a 'charge' of coals is introduced; then the cover is screwed on the end, and made air-tight by a cement of clay and lime. Thus the retorts remain for about five hours, during which the fireplace is opened every hour for the renewal of the fuel with which the retorts are heated; and at the end of this time all the gaseous and vaporizable matters having left the coal, and passed up from each retort by a pipe into the 'hydraulic main,' the 'drawing of the retorts' commences. The retort-cover is loosened by turning a screw; a slight explosion takes place when communication with the atmosphere is opened; the cover is removed by the sooty and almost fireproof hands of the men, and the coke is drawn out by means of rakes eight or ten feet long. A kind of box, made entirely of iron, and placed upon wheels, is wheeled beneath the front of the retorts, and into it a portion of the fiery contents of each retort is drawn. The box is wheeled away, and in a few minutes volumes of steam are ascending profusely from it, the result of a plentiful supply of water, which is thrown on it for the sake of speedy cooling. The remainder of the coke is then drawn out on the iron floor of the building, and, after being partially cooled by water, is removed out into the open air.

In the upper part of every retort is an opening, from which ascends a vertical pipe three or four inches in diameter. The gas, as it is formed, having no other outlet, ascends this pipe, passes thence to another pipe placed horizontally, and then enters a descending pipe, which dips into a large main fourteen or fifteen inches in diameter. This main is placed horizontally along the whole length of the retort-house, and receives all the gas from the whole range of retorts on one side, there being two mains on opposite sides of each retort-house. In these mains commences that purification of the gas which is the object of four successive processes, carried on in four distinct kinds of apparatus, viz. the hydraulic mains, the condensers, the purifiers, and the saturators. As may be readily supposed, the transference of the various products—such as gas, tar, ammoniacal liquor, &c.—from vessel to vessel, requires a large assemblage of pipes, some of which are carried under ground, and others within view.

The retort-houses, such as we have just described, are four in number: two situated in the northern quadrangle, and the other two being placed parallel and contiguous in the central building of the southern quadrangle. From these we pass to a series of smaller rooms attached to the southern end of the retort-houses, and within view from the entrance-gates. One of these is the office of the deputy-superintendent of the works, and the other two contain very ingenious specimens of apparatus, whereby he can regulate the supply of gas at all hours of the day, calculate how much gas has been made within a certain period, ascertain the rate at which it is being manufactured at any particular time, and keep a check over the labours of the men. One of these rooms is called the 'valve-room,' and contains the apparatus for regulating the pressure and supply of the gas. To understand the use of such apparatus, it is necessary to recall to mind the striking change which occurs throughout London as evening is drawing on. The lamplighter is seen busily hastening from lamp to lamp, placing his slight ladder against the street lamp-irons, and kindling the flames which give to our streets no small share of their evening attractions; the shopkeeper begins to illuminate his wares, with one blaze if he be an humble dealer, with a dozen if his house be a 'gin palace,' with a score or two if he sells 'unparalleled bargains' in linen drapery; the theatres, the club-houses, the evening exhibition rooms—all begin to display a blaze of light near about one time. Now it must be obvious, that the sudden demand thus created is enormous, and it may easily be conceived that great judgment is required in adjusting the supply. In order that the gas may be propelled through the main pipes from the factory to the remotest point supplied from the works, it is necessary to give the gas a pressure or elastic force greater than that of the atmosphere. If this pressure be too small, the lights at remote places would burn much too faintly; if

too large, the flames would become so strong as to consume an inordinate quantity of gas: if the gas flowed from the gasometers at an hour before dusk at the same rate as an hour after dusk, the utmost confusion and irregularity would occur. To obviate these evils is the object of the pressure apparatus. Around the valve-room are placed valves connected with each great main. There are six mains branching out from the factory in as many different directions, for the supply of different parts of the town; and as each main requires a supply of gas proportionate to the nature and extent of the district through which it passes, a pressure apparatus is attached to it distinct from the others. Directing our attention to one main only, we may state that, after the gas leaves the gasometers and enters the main, it is placed in communication with a small tube leading to a 'pressure indicator,' by which the exact pressure at any time of the day or night is determined. So long as the pressure is such as is required, no changes are made; but when it is either too great, or too small, recourse is had to a valve whose interior apparatus is in connection with the main. If the pressure is too great, the valve is drawn partly across the main, by which the supply of gas is slackened: if too small, the valve is opened more than before, to admit a greater volume of gas. These adjustments are, as was before observed, made in the 'valve-room,' every main having its own 'pressure indicator' and its own valve.

A room adjacent to the one just mentioned, and called the 'meter-room,' exhibits to view a cast-iron case of a very tasteful kind. This case is probably about ten feet square and seven or eight feet high, and occupies the centre of the room. On the front are six or eight small dials, like clock-faces, and at the back are two pipes ascending through the floor, and entering the case. The case is decorated with much elegance, and the motto, "*Ex fumo dare lucem*," expresses, not inappropriately, the light-giving object of the whole establishment. All the gas made at the works passes into this case or 'meter' by one of the pipes just spoken of, and leaves it by the other. The meter will contain a certain known quantity of gas; and while this quantity is passing through the machine, an index hand is caused, by mechanism within the case, to revolve once round a dial-plate. Every ten revolutions of this hand causes another index to revolve once round another dial-plate; ten of these latter revolutions cause one revolution of a third index; and so on through six successive stages, the last index revolving only once while a million cubic feet of gas are passing through the meter. The superintendent, by looking at the indications in these six dial-faces, is thus able to tell, even to a single foot, how much gas has passed through the meter to the main pipes. There are two other dials on the front of the meter, one of which is a regular clock, and the other an ingenious arrangement for showing the rate at which the gas is passing through the meter at any particular time.

The operations of a gas factory are interminable from the beginning to the end of the year. No cessation, even for a moment, occurs in the labours. One party of men are engaged at night; another party relieve them after an interval of twelve hours, and are employed by day; but the furnaces are always heated, the retorts always supplied with their fiercely-burning contents, the gas always undergoing the purifying processes previous to its passage into the gasometers. The number of retorts worked varies at different seasons of the year, according to the length of time between sunset and sunrise; for the gas manufacturer is regulated more perhaps than most other manufacturers, by the movements of the sun. But whether the number actually worked at any one time be greater or smaller, the system pursued is nearly the same. At the works we have noticed, the retorts are so divided into groups that some of them shall be ready for 'drawing' every hour. If we suppose, for instance, that a charge of coals remains five hours in the retort, and that the retorts are divided into five parcels or sets, one set would be filled (say) at noon, another at one o'clock, and the rest at two, three, and four o'clock respectively. Then, by five o'clock the first set of retorts are ready to be drawn; at six o'clock the second set; and so on with the others. The precise arrangements we need not enter into, but it will suffice to say, that exactly as the clock strikes each successive hour, the men loosen and remove the covers of the retorts, draw out a portion of the coke into large iron boxes, draw out the rest upon the iron floor of the retort-house, throw water on the coke preparatory to its removal from the retort-house, recharge the retorts with fresh coal, replenish the fires with a fresh supply of coke, and fit the covers—coated on their inner surface with a thick layer of lime and clay cement—firmly on the mouths of the retorts. In the intervals which elapse between the successive 'drawings,' the men are employed in pouring the lime-water into the troughs beneath the fireplaces, in placing new layers of cement on the retort-covers to be used after the next drawing, in carrying out the coke into the open air, and afterwards into the sheds or stores, in bringing coals from the coal-stores to the retort-houses, in removing the ashes which fall into the lime-water in the ash-pit, and in various other duties subsidiary to the manufacture of gas. The subsequent preparation or rather perfecting of the gas, demands but a small amount of manual labour; it is, in fact, performed by the steam-engine, which pumps up the water from the well, transfers from vessel to vessel the tar and the ammoniacal liquor abstracted from the gas, and sets in rotation the arms or fans in the purifying vessels.

There is, perhaps, no part of the gas mechanism which requires better workmanship and more careful attention, than the pipes which convey the invisible agent from the works to the places where it is consumed. However perfect may be the mode in which the gas is manufactured, however plentiful the supply, yet if the pipes are either too small or too large, if they are laid either too horizontal or too much inclined, if any of the innumerable joints are imperfectly fitted, the most serious inconvenience results. The mains vary from three inches to eighteen inches in diameter, independent of the small lateral pipes which proceed from the mains into the houses. The largest mains are placed nearest to the gas-works; the next in size are appropriated to the leading streets and thoroughfares; while the smaller are for the less important lanes and streets. Where the streets are wide, and the number of lights required large, it is usual to lay mains on both sides of the street; and the diameters of these mains are made to depend, not only on the magnitude and importance of the street, but on its elevation, its distance from the works, and other circumstances. There is a circumstance attended to in laying down the mains which is perhaps not generally known. They are laid with a gradual inclination, amounting perhaps to an inch in ten or twelve yards, instead of being horizontal; and when this slope has continued for one or two hundred yards, the mains begin to ascend in a similar degree. The line of mains thus ascends and descends alternately throughout its whole length. The reason for this arrangement is, that a small deposition of fluid takes place in the mains; and this fluid, by flowing down the inclined pipes, accumulates, at the lower points, where two descending lines meet; here a reservoir is formed, into which the liquid flows, and by the occasional use of a small pump from above the inconvenience is removed.

How few persons would guess the length of these underground arteries! How few would suppose that the mains proceeding from one of the metropolitan works alone, and ramifying through the streets at the west end of the town, would, if laid in a straight line, reach from London to Bristol; or, if combined with the 'service pipes' which pass from the mains to the houses, extend from London to Exeter! Yet such is the case. Rapid as has been the erection of new houses, the extension of the gas manufacture has proceeded with immeasurably greater rapidity. In the year 1814, there was only *one* gasometer at the Westminster station of the Chartered Company, then the only company in London, and this gasometer held only fourteen thousand cubic feet. By the year 1822, according to a report on the various gas-works, presented by Sir William Congreve to the Secretary of State, the Westminster works had reached the following position:—"The whole number of retorts which were fixed was 300

the greatest number working at any time, 221; the least number, 87. Fifteen gasometers, varying in dimensions, the contents computed at 20,626 cubic feet each, amounting to 309,385 cubic feet altogether, but never quite filled. The extent of mains belonging to this station is about 57 miles; the produce of gas, from 10,000 to 11,000 cubic feet from a chaldron of coals. The weekly consumption of coals is reckoned at forty-two bushels for each retort, amounting to about 602 chaldrons; and, taking the average number of retorts worked at this station at 153, this would give an annual consumption of coals of upwards of 9,282 chaldrons, producing 111,384,000 cubic feet of gas. The average number of lights during the year 1822, was 10,660 private, 2,248 street lamps, and 3,894 theatre lamps." In the interval which has elapsed since this report was made, great extension has taken place in all the operations of the gas manufacture, both in the number of works, and in the quantity of gas made at each.

Whether or not we accept the motto used by Mr. Matthews in his work on Gas Lighting,—

"This is an art which doth excel nature,"

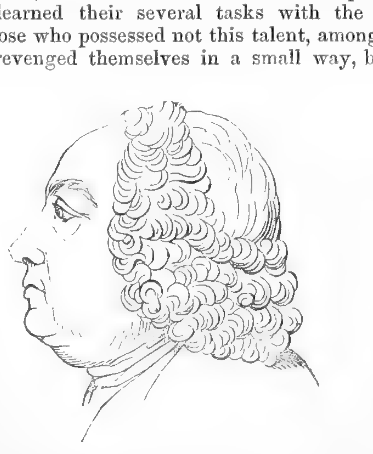
there is abundant room for admiration and congratulation in the history and application of this light-giving agent; and the following statement from the 'Penny Cyclopædia,' shows how extensively the advantages are now appreciated:—"Every large town in Great Britain has long had gas; the smaller towns have followed, and there is now scarcely a place in the kingdom without it. The continental nations have slowly followed our example; Paris for some years, and more recently the towns of Lyons, Marseilles, Bordeaux, Nantes, Caen, Boulogne, Amiens, and several others, have adopted it. It is in use in many parts of Germany and Belgium, and St. Petersburgh has a small establishment, which is rapidly increasing under the superintendence of a gentleman from one of the London works. The larger towns in the United States also burn gas; and even in the remote colony of New South Wales, the town of Sydney has introduced this valuable invention, which we have no doubt will be found there, as it has been in London, as useful in preventing nocturnal outrage as an army of watchmen."

PHRENOLOGY.

CHAPTER XV.

INTELLECTUAL FACULTIES—CONTINUED.

33. Language is situated about the middle of the orbitar process of the frontal bone, and, when large, gives fulness to the eyes. The scholars whom Dr. Gall had the greatest difficulty of competing with, were those who had the most prominent eyes. These learned their several tasks with the utmost facility, and those who possessed not this talent, among whom was Dr. Gall, revenged themselves in a small way, by nick-



naming them *ox-eyed*. To the observation of Dr. Gall in this respect, we primarily owe the establishment of this science. Whatever seminary Dr. Gall studied at, he invariably observed that the *ox-eyed* students always learned by heart with the greatest ease; and though they were, in many instances, much inferior in real talents to those whom they eclipsed in the learning of words, yet this very circumstance drew upon the others very severe rebukes from the different teachers.—[This is also the case at the present day among teachers. When phrenology has made sufficient progress that teachers have become acquainted with its principles, they will cease to exact from their pupils those long catalogues of words which are acquired with great pain, and forgotten with real pleasure.]—Dr. Gall continued to make his observations on this circumstance, and the organ is now fully established. The special function of this organ is explained in its name; and may be considered as the power by which language itself is acquired, whether the language be native or foreign, dead or living. Persons who have a large endowment of this faculty abound in words: there seems to be no lack; like a copious stream, they pour forth words in a torrent of profusion, and seem never at a loss for an expression by which to give utterance to their ideas. The faculty, it is evident, must be of the highest importance to all men, but especially to those who are engaged in public speaking and teaching. No one can excel in extemporaneous speaking, who has not a full endowment of this faculty. It seems a gift which is especially necessary to the minister of the gospel, because he is to be prepared for his Master's work *in season* and *out of season*; and from the observation of our Saviour, that he would give to his faithful disciples a mouth and wisdom, which all their adversaries should be incapable of gainsaying or resisting, we should almost assume that the individual in whom this organ is not *full*, is scarcely in his proper place as a minister or teacher of the gospel. Extemporaneous speaking must also be of great use among statesmen, since numerous observations will be introduced in debate, which require a special answer. In a work published some years ago, entitled "Random Recollections of the House of Commons," several of the principal speakers are hit off with great dexterity. We will select two instances as illustrations. First, Lord John Russell, who is at the head of the whig party; and second, the late Daniel O'Connell, who had a party of his own, but still was claimed by the radicals. Lord John Russell is one of the worst speakers in the House, and but for his excellent private character, his family connections, and his consequent influence in the political world, he would not be tolerated. His voice is weak, and his enunciation very imperfect. He speaks, in general, in so low a tone as to be inaudible to more than one-half of the House. His style is often in bad taste, and he stammers and mutters at every fourth or fifth sentence. He has an awkward custom of repeating, frequently three or four times, the first two or three words of a sentence, accompanied by a corresponding number of what Shakspeare terms *hems*, when at a loss for terms whereby to express his ideas. For example, in the idea to which he wanted to give expression were, that he thought the motion of a certain honourable member ill-timed, he would express himself in something like this manner in the instance I have supposed:—"I—I—I—hem!—think the motion of the honourable member is—is ill-timed at the—at the—hem!—present moment." This stammering propensity of Lord John Russell will be the result of large Cautiousness and but moderate Language, and a person of this description will never excel as an extempore speaker. But perhaps the most powerful, as he was certainly the most popular, speaker was on the Radical side of the house. I mean O'Connell. He is thus described:—"Mr. O'Connell is a man of the highest order of genius. There is not a member in the House who, in this repect, can compete with him. You see the greatness of his genius in almost every thing he utters. There are others—Sir Robert Peel, for example—who have much more tact and greater dexterity in debate; but, in point of genius, none approach to him. It ever and anon bursts forth with a brilliancy and effect which are quite overwhelming. What greatly adds to the effect of Mr. O'Connell's genius is, that you see at once that it is *perfectly spontaneous*—the result of the feeling of the moment, and not of careful thought in a previous preparation of his speech." This is the result of brain of great power, and of organs developed with unusual felicity. In O'Connell there will be full

Language, indomitable firmness, inflexible courage, which is the result of large Combativeness, and a withering sarcasm and powerful irony—the results of large Wit and Destructiveness. A man of this kind, open and generous like the generality of his countrymen, will neither be restrained by prudence nor caution. We should, therefore, infer that he would, in Secretiveness and Cautiousness, be but moderately developed. He will pour forth a wordy torrent, in which all the powers of language will be associated, and carry with him all whose hearts and heads are not previously warped by prejudice.

Extemporaneous speaking must not only be of use to the statesman, but to the lawyer also. He who relies only upon his brief, will be incapable of meeting any unexpected arguments of his opponent, and his client will in consequence be sure of suffering. On the contrary, he in whom Language is large, with the reflecting and perceptive faculties in combination, will excel in extemporaneous oratory, and, if combined with large Combativeness, can scarcely faii of meeting the most perplexing and unexpected difficulties. An instance of this kind occurred in the Common Pleas, London. The counsel in a plaintiff's cause coming hastily into court, and being as hastily called upon, took up by mistake the opposite counsel's brief, and running his eye hastily over it, and imagining it his own client's, began most energetically to plead against his own client. The solicitor of the cause and the witnesses, as well as the miserable plaintiff himself, all tried to gain his eye, and explain to him the nature of his mistake, but in vain. Carried away by his feelings, he kept most eloquently pleading *against* his client, who, in agony, when he had nearly finished, thrust into his hand a bit of paper, on which was written in pencil—"You have pleaded on the wrong side!" Instantly comprehending the mistake, and calling to remembrance the attempts at interruption which he before paid no regard to, he continued in the same strain, but arriving at the conclusion, as it was thought, of his speech, he suddenly exclaimed—"All this, my Lord, and no doubt much more to the same purpose, you will hear from my learned friend on the opposite side; but I shall speedily show the fallacy of such reasoning." He then commenced a second time, went over all the points of the case, nor stopped till he had energetically refuted himself from beginning to end, and a verdict was thus gained for his client. Now, suppose this individual had been tied down to a brief, and could say not a word but what he had studied, he hardly could have failed, in the present instance, of losing his client's cause. In the pulpit, then, in the senate, and at the bar, extemporaneous speaking must be allowed to be eminently useful, and unless an individual be endowed with Language freely developed, he is not likely to excel in such professions. But here, of course, this faculty would be of little use, unless associated with well-developed perceptive and reflecting organs. Persons may have large endowments of language, and yet be little better than parrots, making use of many words, but imperfectly or not at all acquainted with their meaning. This is very happily satirized in the comedy of the *Rivals*, in a letter sent to Lucius O'Trigger by Mrs. Malaprop:—

"There is often a sudden incentive impulse in love, that has a greater induction than years of *domestic combination.* Such was the *commotion* I felt at the first *superfluous* view of Sir Lucius O'Trigger. Female *punctuation* forbids my saying any more, yet let me add, that it will give me joy *infallible* to find Sir Lucius worthy the last *criterion* of my affections.

"Yours while *meretricious*,

"Delia."

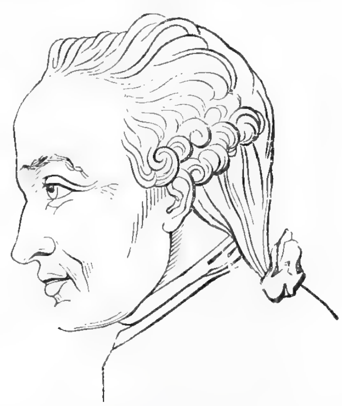
Never was language more perversely tortured than in the short note of the love-sick Mrs. Malaprop; but do not let it be supposed that the picture is in all respects too highly coloured, or the abuse of language too glaringly exhibited. We know an instance where, though it was not so outrageously displayed, was yet rendered much worse by its proceeding from an individual who imagined himself a capital preacher. The ludicrous malaprops which he introduced kept his audience in a perpetual titter. In short, his discourse could not be better characterized than as consisting of "Words—words—words."

In the cultivation of the faculty of language, it is much to be lamented that children's memories are generally overloaded with an abundance of words, of the meaning of which they are almost wholly ignorant. Pestalozzi recommended to his disciples, that the best method of learning boys a language was to permit them to progress in the knowledge of words no further than they could comprehend them. Let them write down half a dozen words; then find out their derivation; then proceed to form them into sentences, and this will exercise all their faculties; whereas any child may be taught to repeat *words*, although of the true meaning of them he may continue in hopeless ignorance. "Great linguists (says the Book of Aphorisms) are for the most part great blockheads." I say nothing of Sir William Jones, the admirable Crichton, and other exceptions to the rule. But, generally speaking, what I say holds true. To master a variety of languages requires only one talent, and that by no means a high one, viz., a good verbal memory, which is sometimes possessed, in great perfection, even by simpletons and idiots. It is difficult for men of very strong and original minds to become good linguists. They are so much taken up with substantialities, that they think little about words. The knowledge of a number of languages does not communicate a single new idea. It only gives the power of expressing what you already know in a variety of ways. "I would rather (says Dr. Spurzheim) acquire one new idea, than twenty ways of expressing an old one. If men of great genius are occasionally formidable as linguists, they are so in spite of their genius, which rather stands in their way than assists them; and they would have been still greater linguists if they had possessed their powerful verbal memory unaccompanied with less original talent." When a person is found deficient in words to express his ideas, although his ideas may be very distinct before him, he may, to a certain extent, remedy the defect by learning pieces by heart, or translating into his own, pieces from a foreign language.

Genus III.—REFLECTING FACULTIES.

These powers constitute what is usually denominated reason. They are the supreme powers of the intellect, and contribute to direct and assist the respective faculties in their various duties.

34. Comparison.—This organ is situated in the upper part of the forehead, with Eventuality before and Benevolence behind. Of this organ Dr. Spurzheim remarks:—"Each other intellectual faculty compares its own appropriate and peculiar notions. Melody, for instance, compares tones; Colouring, colours; Configuration, forms; Calculation, numbers, &c.; but this special power compares the functions of all the other primitive faculties, points out resemblances, analogies, identities, and differences. Its essential nature is to compare. It is therefore fond of analogies, in the same way as Melody



likes the harmony of tones, and Colouring the harmony of colours; but it also appreciates differences, just as Melody and Colouring feel discords among their respective impressions. Differences, in fact, are the discords of the faculty of Comparison. This power produces discrimination, generalization, abstraction, and induces the mind, wishing to communicate unknown ideas, to refer and to illustrate by such as are known,

or to speak in examples. It is destined to establish harmony among all mental phenomena. By the influence of this power, artificial signs become figurative. The nations, consequently, who have it active, have a metaphorical language."

Dr. Gall relates that he often conversed on philosophical subjects with a philosopher who possessed much vivacity; but whenever he found difficulty in proving any particular proposition, he invariably had recourse to comparison. In this manner his ideas were painted in vivid imagery, and his opponents were carried along by his analogies, and in this way his success was great.

As soon as Dr. Gall perceived that this was a peculiar trait of the individual's character, he examined his head, and found an eminence of the form of a reversed pyramid in the upper and middle portion of the frontal bone. From his observations on this philosopher, he proceeded to examine the heads of all persons who manifested a similar plan of reasoning, and found that the configuration was in all alike. He therefore marked the organ as that of sagacity or perspicuity. It is now established as Comparison.

This organ is the predominating one in our own head, and as the Scriptures abound with analogies, we shall give our views of them as we proceed.

The functions of this organ are in different individuals variously manifested, and takes the turn of the predominant organs. In him where there is a large Locality, it will tend to the comparison of animals, birds, and vegetables; with particular persons in other countries, especially if Locality and Comparison be combined with large Eventuality and Individuality. In him where the knowing organs predominate, the analogies will be from mechanism. Thus it is observed by Mr. Combe, that Dr. Chalmers, in whose mask the knowing organs are large, and in whom also Comparison is equally well developed, takes his analogies from astronomy and the mechanical laws. Amongst the ancients, the doctrine of analogies was cultivated with very considerable attention. The Egyptians, in particular, excelled in it, and the hieroglyphics of that people seem to be principally derived from it. When they made images of horses, oxen, calves, serpents, and other animals, they appear to have done so for the express purpose of personifying the qualities of the animals. In mythology we read of the pegasus, or winged horse, which belongs to Apollo and the Muses. Apollo was the god of music, poetry, and intelligence, while the Muses were the mistresses of all the sciences, and prompted the votaries of Apollo to the exercise of their various powers in praise of the god. The pegasus, or winged horse, is stated to have opened a fountain of water by striking a rock with his hoof, and afterwards it fled up to heaven, where it became a constellation. Now this fable owes its origin to the doctrine of analogies. A fountain of water is both of a purifying and satisfying nature. It is purifying, because by water the bodily impurities and defilements of man are cleansed; and it is satisfying, because by it man's thirst is quenched. The horse, on account of the rapidity of his motions and the beauty of his form, is one of the most noble and useful of the lower animals, and, being here represented as possessed of wings, the power of his speed is of course increased. Man, by virtue of his understanding, is the most noble of all animals, and his thoughts are to him the wings by which he can take the most extraordinary flights. Though his body be upon earth, his understanding can fly up to the heavens. He can take the wings of the morning—the rays of intelligence from his understanding— and fly to the uttermost parts of the earth. He can behold at a glance all the kingdoms of the earth, and the glory of them. He can perceive the thousands of devout, but to him infatuated pilgrims that throng the shrine of the Prophet at Mecca. He can behold and wonder at the insane fanaticism of the worshippers of the idol Juggernaut, and he can pity while he contemplates the delusions of the Christian, in worshipping or bowing down before an image of a sanctified person, whom his own hands may probably have made, and his own imagination has canonized as a saint. With Byron, he can behold the ruins of Greece, and recline as his gondolier rows him over the river of once imperial Venice. With Scott he can wander in the deep ravines, or climb the craggy mountains, or behold the glens, the woods, the cataracts, the lochs, and all the thousand beauties of this romantic land, and yet, while enjoying all this, and his mind taking this rapid flight, he is quietly sitting by his own fireside, and enjoying himself in all the luxuries of travelling, without being wearied by any of its fatigues. The horse, then, is in man his powerful and vigorous understanding, and his wings are those thoughts which can take the wide range we have just described. When an individual is indulging in the flights of the imagination, how often do we hear people exclaim—O! he is mounted on his pegasus; he is soaring in the clouds; he is taking an elevated flight; when he returns we shall no doubt have news from the moon. All these figures of speech have their origin in the doctrine of analogies. And when a powerful understanding lays open before others some of the mighty workings of his own mighty mind, which their obtuseness may prevent them from perceiving—Oh! say they, he is riding a high horse; when he descends from his back he will perhaps tell us, in sober language, what he means—when the individual is all the while sitting soberly with them in a room, or walking, while he is conversing, over the dull grey earth of this sublunary sphere. In this instance, then, as in the former, the pegasus and the high horse are but imaginary, and really refer to the power of the man's *understanding*. If we now examine the fable of the winged horse by such analogies as constitute it, we shall find the horse denotes the understanding; its hoof, which it struck against a rock, the lowest principle or basis of the understanding; its wings, by which it ascended into heaven, the highest intelligence of the mind, by which it acquires all wisdom and knowledge; and its being fixed as a constellation of light in the heavens, denotes that superior intelligence which has been acquired in its rapid flight through the world, and which, as a sparkling star, now assists in enlightening the world. The Scriptures are full of these analogies, and not a few of them are illustrated by the horse. In Psalm xxxiii. 17—"A horse is a vain thing for safety, neither shall he deliver any by his great strength." Now, if we examine this by analogy, the words are strictly true; but if we take them literally, they can by no means be admitted. How often do we read in history that such or such an individual owed his safety to the fleetness of his steed, and but for that circumstance he would have been made a prisoner? In such instances, surely, the horse is not "a vain thing for safety," and many a one has been delivered by his great strength. But if we admit the subject to be analogically put, then its force and power is immediately perceived. In the first place, the horse bears an analogy to the understanding of man. But this understanding has been given him by a superior power, and must be held by man under such an acknowledgment. Now, if he arrogate all the power to himself, he becomes the overbearing, proud, and domineering tyrant who is too frequently and too unhappily perceived by his fellow-creatures, who become, in many instances, the mere slaves of arbitrary power. Such a man relies all upon his own understanding, acknowledges no superior power, and despises every one in comparison with himself. Now, it is to such persons the Bible addresses itself in language—"*A horse.*" It is thus by natural imagery that man is perpetually addressed in the sacred volume, and it is only by reasoning in this way that the more abstruse parts of the Bible can be apprehended; and, indeed, by the faculty of Comparison all difficulties may be said to vanish. Here phrenology is indeed valuable. Our authority for this is St. Paul. He observes—"The INVISIBLE things of God from the creation of the world are clearly seen, being understood by the things that are made." INVISIBLE THINGS SEEN! Yes, but through the medium of the visible. Thus Jesus Christ is the express image of his Father's person. Now the Father is invisible. No man hath seen or can see him; but Jesus Christ, his only-begotten Son, has brought him forth to view. This is a satisfactory answer to the hitherto perplexing question—*In what form is God?* Jesus Christ is in the *human form*, and he is declared to be the express image of his Father's person, and his Father must therefore be in the human form. In this most important of all truths, the apostolic words are verified, the *invisible* is rendered perceptible by the *visible*. Continue to apply the faculty of Comparison

for the understanding of the Scriptures, and it will be found invaluable. For this purpose, let all animals mentioned in the Bible be referred to the great powers of the mind, which constitute man, *i. e.*, his will and his understanding. For instance, where innocence and purity is typified, by what can it be more aptly symbolized than the *lamb?* and hence Jesus Christ is called the *Lamb of God.* Where unsuspecting honesty and simple humility, though attended with occasional irrascibility of temper, is descibed, the *ox* is referred to; and how often man changes his glory into the similitude of an ox, need not here be noticed. Again, when rapine and cruelty are spoken of, the *wolf* is introduced; and where Destructiveness evidences itself in the fiercest of the animal tribe of mammalia, the *lion* is symbolized. In this sense Zephaniah iii. 3, describes the princes and judges of an oppressed city in these words—" Her princes within her are *roaring lions*, her judges are *evening wolves*." Our Saviour also called Herod a *fox*, indicative of his qualities of deceit and cunning. In all these instances the low propensities of man are referred to. The lamb, a state of simple innocence, refers to attachment, or Adhesiveness and Philoprogenitiveness. The ox of friendship, with some irritability, to Adhesiveness and Combativeness. The wolf and lion, to strength and Destructiveness, with Secretiveness combined; and the fox, of the same powers, with greater Secretiveness. The analogies of the faculties in the cerebrum are equally striking. We have seen this in the instance of the winged horse; but it is equally discoverable in the Bible. When man's thoughts tend to innocence and truth, his understanding, as it beholds the fraud and violence of the world, mentally exclaims—" O! that I had wings like a dove; for then would I fly away and be at rest." When pride lifts up the mind, his thoughts, like the eagle, soar to the cliffs of the rocks; but his pride, having climbed so high, experiences, with greater bitterness and anguish, the fall which sooner or later must come upon him. The parables of our Saviour are, generally speaking, striking illustrations of the faculty of Comparison. The parable of the woman who had lost a piece of silver is a powerful evidence of this. The subject analogized was the kingdom of heaven. The woman typified the church; the piece of silver, from its bright and shining properties, the truth of that church, which by evil had become lost; the lighting of a candle to seek for it, symbolizes the great necessity of our using those powers of the understanding, or eye of the mind, by which alone we can discover truth when we have it presented before us. The seeking diligently, implies the exploration of all the principles of the mind; and the finding the piece, and calling all her friends and neighbours to rejoice with her, implies that inward gratification and joy which, when a great benefit is discovered, desires that others should partake of our happiness. And the ceremonies of the Jews are also, by the same laws of analogy, applicable to us, which, by the believer of the book of God, must be admitted; because " the law was our schoolmaster to bring us to Christ, and all things which happened to the Jews happened to them as examples to us, to whom the ends of the world are come." One powerful proof of this we shall select from the wars of the Israelites and Philistines, in the capture of the ark, and in its return, with the trespass-offering of golden emerods and mice. The Philistines, having captured the ark, conveyed it to the house of Dagon their god in triumph, where they left it. But on the next morning Dagon was fallen on his face before the ark. Supposing this to be an accident, they set him up again in his place; but again, on their visiting their idolatrous temple, Dagon was not only again fallen, but grievously mutilated. Immediately after this, disease attacked the Philistines, and their whole land was overrun with mice. They were now as anxious to get rid of the ark, as they were before loud in their triumph for its capture. So, calling their priests and divines together, they consulted what was best to be done in such an emergency. These priests counselled the return of the ark, with a trespass-offering of emerods and mice made of gold. This was agreed to by the lords of the Philistines; the ark was returned, and the disease and the plague of mice both stayed. To understand these analogies, we must first know the nature of the disease, and the quality of the mice, as well as the quality of the people who were infested by them. The emerod is a disease somewhat similar to the piles, occasioned by the impurity of the blood, which collects into small masses, and breaks out into botches over the body. " If," says Moses, " ye will not hearken to the voice of the Lord your God, which I command you this day, the Lord shall smite you with the botch of Egypt, and with the emerods, and with the scab, whereof thou canst not be healed." Here is a want of truth, or Conscientiousness. In examining the propensity of the mouse, we find it to consist of large Cautiousness and large Secretiveness; that is, of great cunning and caution, a constant endeavour to shun observance and avoid the light, together with a destructive and polluting power upon everything which it attacks. The character of the Philistines, as a people who were constantly at war with Israel, represents those who are constantly at war with God. Now, from these descriptions of the emerod, the mouse, and the Philistines, the analogies are of the most instructive kind. As, when the blood is impure the body becomes diseased, so, when the powers of the mind are impure, the soul is diseased. As blood circulates through the body, and gives it a healthy action, so, when intelligence circulates through the mind, a healthy action is also imparted. But in this case the disease is the result of the impurity of the blood, and emerods are therefore symbolic of the appetites of the natural man, which, when separated from the laws of the mind and spirit, as is done by those who do not apply their faith to the purification of their lives, are wholly unclean and polluted. This was the case with the Philistines; they knew what was necessary to be done, but yet they did it not. They continued to worship Dagon, although they knew that such worship, and the profanation of the ark, brought with it all their sufferings. The pollution of the mind was, therefore, evidenced by the polluting power of the disease upon them. To render this still more striking, the land was overrun with mice. This was a further emblem of the destroying and polluting power of evil; and as evil destroys the wicked, can we find a simile more just and appropriate? The mouse shuns the light, and so does falsehood. Why? Because its deeds are evil. A small quantity of poison pollutes and destroys a whole fountain of pure water, and a small quantity of hemorrhoidal poison pollutes and poisons the whole fountain of the blood. Evil is that poison, and the mouse, coupled with the emerod, is an exact resemblance of its debasing and polluting nature. But why, then, it may be asked, return as a trespass-offering images of these very pollutions? The answer is easy. The images were of gold, and gold is symbolic of purity. To return: the images of emerods and mice of pure gold is, therefore, to symbolize that the natural propensities of man have been purified. We hold this as an undeniable proof of the truth of phrenology. All the propensities of man are in themselves useful; but how much they may be abused we have already seen, while treating of the lower propensities. Yet all these may be purified, and when, as in the present case, the purity of gold is brought in to symbolize the complete purification of the lower propensities of man, we again say phrenological truth is evidenced.

In the third letter from Mr. B. to Mr. Cox, inserted in the eighth volume of the Phrenological Journal, page 216, the writer observes:—" I must mention one curious fact. I have a most singular tendency to compare one thing with another. For instance, if I hear the piano played, every sound seems to resemble a particular colour; and so uniform is this, that I could almost make a gamut of colours. Some notes are *yellow;* others, *green;* others, *blue*, and so forth. Words also are associated in my mind with shapes, and shapes with words. A horse's mouth, for instance, I always associate with the word *smear*. As instances of the similitude with words and forms, I say Combe resembles an urn; Cox, a few teeth of a saw; Simpson, an hour-glass laid sideways. This is certainly a very odd peculiarity, and I know not how to account for it, unless it be from a strange activity in the organ of Comparison. It has existed since ever I recollect, and has puzzled myself, as I believe it will do every other person. In writing and reasoning, I feel at once that Comparison is the strongest faculty I have, and I believe there is no person makes a

greater use of similes and illustrations. This was observed by others long before it occurred to myself. Indeed, it never struck me till I was told of it."

The organ of Comparison is also large in myself, and I have frequently used particular associations to remember events in history, without the aid of which, I am, through a deficiency in Individuality, unable to recollect dates. In a system of *Mnemonics*, which I compiled for my own and my children's use some years since, I associated in my mind the accession of Elizabeth with the colour *yellow*. I did this because yellow is the frequent comparison of melancholy; and she was frequently in the melancholy mood. Mary I associated with a *bonfire*. And when the late king, George IV., ascended the throne, and there was a strife between the two great parties in the state, which should get the most plunder, I pictured in my mind the state infested with *vermin*. But I took care, in all these instances, that whatever I associated in my mind should give me an answer to the question, what times the various sovereigns ascended the throne.

35. Causality is situated on each side of Comparison. It has very frequently been observed, that men who possess comprehensive minds, such as Socrates, Bacon, Galileo, and others, have the upper part of the forehead finely and fully prominent. At Vienna, Dr. Gall remarked, that in the most zealous disciples of Kant, men distinguished for profound, penetrating, metaphysical talent, the parts of the brain immediately outwards, and to the sides of the organ of Comparison, were distinctly enlarged. Drs. Gall and Spurzheim, after noticing this configuration in the disciples of Kant, afterwards saw a mask of Kant himself, moulded after death, and perceived an extraordinary projection of these parts. At a later period they became personally acquainted with Fichte, and found a development in that region still larger than in Kant. Innumerable additional observations satisfied them of the functions of this organ. Dr. Gall named it "*Esprit Metaphysique*," but Dr. Spurzheim calls it *Causality*. "The ancient artists," says Dr. Spurzheim, "have given to Jupiter a head more prominent than any other of the antique heads; and hence it would appear that they had observed that the development of the forehead has a relation to a great understanding." Mr. Combe gives some highly interesting illustrations of this faculty. "A gentleman in a boat," says he, "was unexpectedly asked to steer. He took hold of the helm, hesitated a moment what to do, and then steered with just effect. Being asked why he hesitated, he replied—'I was unacquainted with steering, and required to think how the helm acts.' He was requested to explain how thinking led him to the point, and replied that he knew, from study, the theory of the helm's action; that he just run over in his mind the water's action upon it, and its action on the boat, and then he saw the whole plainly before him. He had a large Causality, and not much Individuality. A person with a great Individuality and little Causality, placed in a similar situation, would have tried the experiment of the helm's action to come to a knowledge of the mode of steering. He would have turned it to the right hand and to the left, and observed the effect, then acted accordingly; and he might have steered his whole life thereafter, without knowing any more of the matter." In those persons in whom Causality is large, there is a constant endeavour to trace up things to their proper source. They will not believe the effect, unless to a certain degree they are acquainted with the cause. We should certainly hold the apostle Paul to be an illustration of this faculty, from the circumstance of his using the precept—"Prove all things; hold fast that which is good." So, too, the apostle Peter must have recognised its power, when he exhorted his converts to be always ready to give a reason of the hope that is in them, with meekness and fear.

In persons where Veneration is small, and there is but small Conscientiousness, if there be a large endowment of Causality, it is frequently the cause of denial of a Supreme Being. If you attempt to prove the existence of a Supreme Being to an atheist, he will stop you short with the question—*Who, pray, made God?* In all great and original thinkers, this faculty is largely developed. In the portraits of Bacon and Locke it is eminently conspicuous, and in the bust of Gall it is strikingly large. When the organ is small, the mind is apt to be superficial, and the individual experiences great difficulty in reasoning after a logical manner. Such persons as these will find very great difficulty in receiving the truth of phrenology, because the power of evidence will make but small impression on their minds. This is also one reason why persons who have large Self-Esteem will not admit the evidence of phrenology. They, generally speaking, have too high an opinion of their own discernment to listen to the evidence of others. Thus, then, if Self-Esteem be large, and the reflecting faculties small, it will be almost hopeless to convince such an individual.

The organ of Causality, situated as it is on each side Comparison, seems to act by necessary correspondency. It does not place implicit faith in analogies, and thus acts as a necessary check on the rapid, often plausible, but sometimes erroneous conclusions of Comparison. In searching out causes, it, of necessity, infers a great First Cause. The faculty of Individuality makes us acquainted with objects; that of Eventuality with facts; that of Comparison points out their analogy or difference; and the faculty of Causality desires to know the causes of occurrences. Where all these faculties are fully developed, the truly philosophic understanding is formed.

PORTABLE NON-CONDENSING ENGINE.

BY BENJAMIN HICK AND SON, SOHO IRON WORKS, BOLTON.

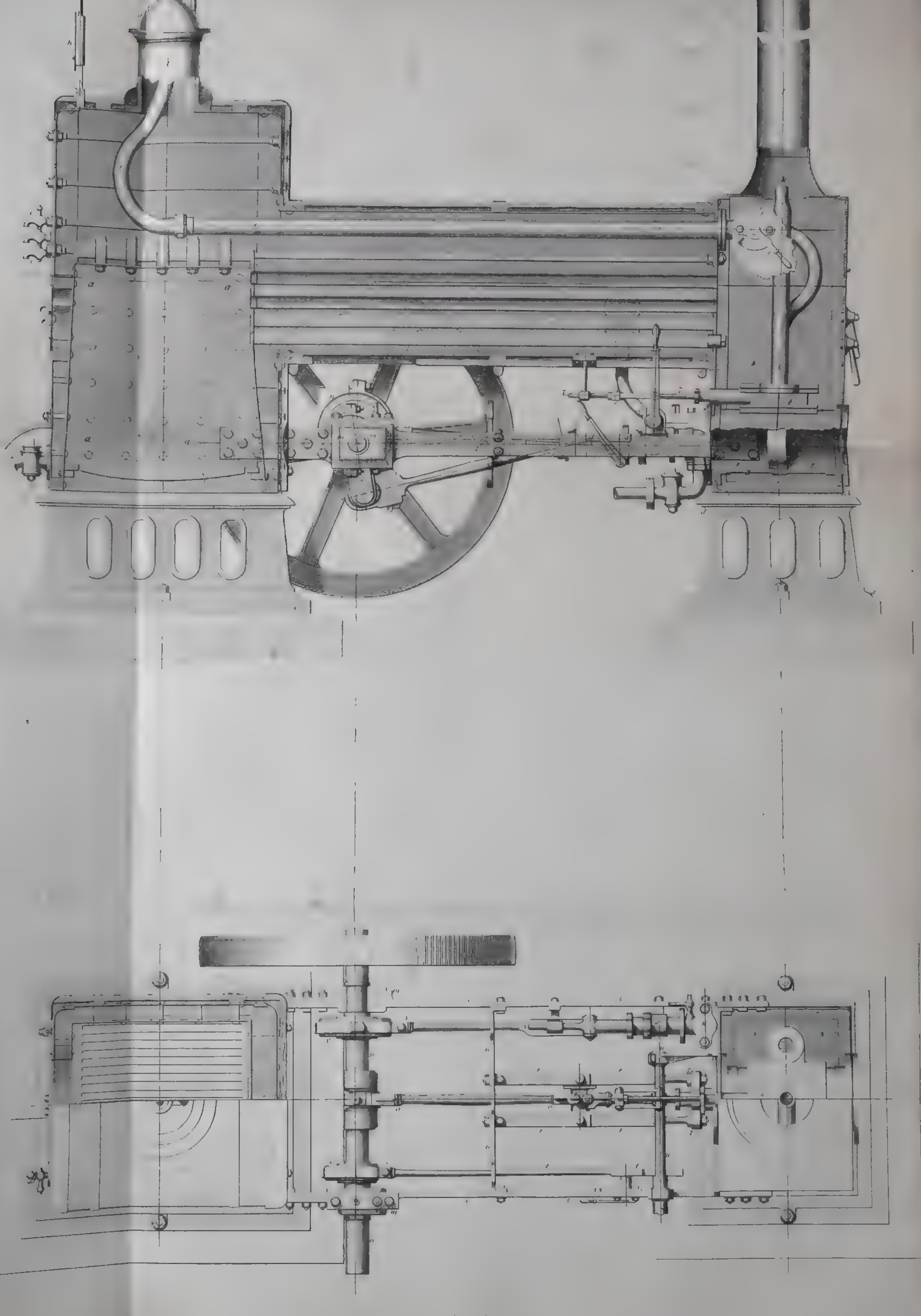
It will be seen from an inspection of the plate, that this novel form of portable high-pressure engine is founded upon the locomotive engine, to which it bears a very close resemblance, as well in the general appearance as in the details of the mechanism. The fire-box, *a a a a*, and the smoke-box, *b b*, are supported upon two elegant bases, leaving a space between, in which the fly-wheel revolves, and, by this arrangement, leaving all the working parts open to inspection.

At the furnace-box, *e*, *e*, are the gauge cocks; *f*, the blow-off cock, by which the boiler is cleaned from deposit, &c.; *g g*, the steam dome, with spring-balance safety-valve, *h h h*. To prevent priming, the steam pipe, *i i i*, opens near the top of the dome, and is regulated in its passage to the cylinder, 3 3, by a throttle-valve, the lever of which is at *j j*. The crank shaft, *n n*, is supported in bearings, *m m*, in the lateral ties, which connect the fire-box and smoke-box on each side (see 5 5, plan); *o o*, the connecting-rod. The parallelism of the piston-rod is effected by the piston-rod cross-head sliding between the two parallel bars, *r r r*, secured to the cross-tie, 6 6, and the cylinder stuffing-box, 7 7. The valve for working the eccentric is at *s s*, *t t*, and is connected with a weigh or rocking-shaft, *u u*. The eccentric for working the pump, *w w*, is at *v v*; 3 3, the cylinder; 4, the steam or valve-chest. This portable engine, from its compactness and ease with which it may be removed from place to place, seems well adapted to farm purposes. From what we know of the general run of agricultural steam engines, their badly proportioned parts, and their liability to get out of repair, we think it would be worth while for farmers to leave off patronizing the parties who introduce such mechanical monstrosities, and to try the work of such firms as the one to whom the form we have described owes its introduction. They would thus discover that they were capable of performing the work which they were stated to be capable of, and that frequent necessity for repair is not always an attendant upon the use of steam-engine power. We feel quite convinced, that if makers of steam engines, who are accustomed to send out the first-class quality of work desiderated in the manufacturing districts, were to devote a part of their time to the construction of engines for agricultural operation, that they would be amply repaid. There is a wide field for the use of well-devised farm mechanism of all kinds. There is a vast deal of quackery in this department, which can only be effectually done away with by the entry of first-rate mechanism in the field of operation. These remarks apply, in no degree, to the engineers who are at the head of agricultural engineering. These have already done much to remove this quackery system, but there is still "ample room and verge enough" for our manufacturing engineers.

PORTABLE NONCONDENSING ENGINE

As Constructed by

BENJ^N HICK & SON SOHO IRON WORKS BOLTON



CHEMICAL MANUFACTURES.

CHAPTER VI.

THE MANUFACTURE OF SODA.

As there do not appear, in common life, to be very many uses for sulphuric acid on a large scale, it may seem strange why such vast quantities should be made; since a large portion of all the sulphur imported is used in making this acid, and the acid produced is nearly three times as great in weight as the sulphur employed. But, as was before observed, it is as an agent in producing many other important chemical substances that this acid is so largely used; and to some of these, attention may next be directed.

We described in last chapter the preparation of sulphuric acid, or oil of vitriol. *Soda*, a substance so largely employed in glass-making, in soap-making, in bleaching, in washing, and in many other operations, is at the present day produced by the application of sulphuric acid to common salt; and the manufacture is one of those carried on at many of the large chemical works. Most remarkable have been the changes in the mode of producing this useful alkali. Some years ago the duty on salt (now employed in the manufacture) was almost unprecedentedly high: it amounted to £30 per ton; whereas the commodity can at the present day be purchased for ten or twelve shillings per ton: that is, the duty was once fifty or sixty times as great as the article itself can now be actually bought for! Under these circumstances, the production of soda from this substance was not thought of commercially. At that time the soda was prepared from *kelp*, a kind of sea-weed found on the shores of the Scottish highlands and islands, in a manner which we shall notice when speaking of the soap manufacture. *Barilla*, obtained from the ash of an Italian sea-weed, was also employed for the same purpose. But common rock-salt has now nearly superseded the latter, and wholly so the former. Indeed, so marked has been the change, that though the commercial and manufacturing advantages have been immense, the result has been in some respects painful, since the Highlanders who used to be employed in the kelp manufacture are now wholly deprived of that source of income.

Common salt is chemically designated chloride of sodium; common soda is chemically carbonate of soda; and the process of manufacture consists in separating the sodium from the chlorine, and making it the chief element in a new compound. It instructively illustrates the way in which one chemical process necessarily involves another—that the very same operation which leads to the production of carbonate of soda from one element of the salt, leads to the production of muriatic acid from the other. So rapidly has this branch of manufacture extended, that it was estimated, in 1838, that more than seventy thousand tons of carbonate of soda were made from common salt in that year.

The ancients, and even the moderns, until within the last century, were unaware of the real difference between the two alkalies, soda and potash, and supposed their different characteristics to arise from accidental circumstances, such as the peculiarities of their preparation or the nature of the plant itself, which, in their opinion, really made the alkali; and as lately as the year 1736, soda and potash were regarded as the same substance. At that time, Henry Louis Duhamel du Monceau* demonstrated, by conclusive evidence, the peculiar nature of soda, and its distinctness from its congener potash. This important fact was confirmed by Margraaf in 1758, and though of considerable importance to the arts, yet for many years it was regarded as a mere scientific fact, and its practical application entirely neglected.

* In 1718, the saffron (Crocus sativus, or Saffron crocus), in various parts of France, was destroyed by a disease apparently *similar to that now attacking potatoes*. Duhamel's property suffered severely, and although only eighteen years of age, he was commissioned by government to inquire into the cause of the malady, which, after a long investigation, he declared to arise from a parasitical plant or fungus, which extended through the ground from one plant to another, and destroyed the bulb by feeding on it.

About 1730, the manufacture of kelp was introduced into the Highlands from Ireland, where it had been practised for a few years, but very little progress was made in the trade until 1783, when Baron Louis Bernard Guyton de Morveau, a philosopher of considerable note, and practising as a lawyer in Dijon, obtained permission to establish a manufactory for the preparation of soda from "barilla" (incinerated seaweed), which was the first introduction of the manufacture into France. Five or six years previously, Morveau had founded a very considerable establishment for the manufacture of saltpetre, which called forth the thanks of the king, through M. Necker, minister of finance. He was also the first to make use of acid fumes for the purpose of destroying effluvia or malaria; in 1772, one of the churches in Dijon had been so overcrowded by interments within the building, that the inhabitants of the town were seized with a malignant disorder, engendered by the pestiferous exhalation from the putrescent matter, which proved nearly as fatal as the plague. By closing the church and filling it with muriatic acid gas, evolved from a mixture of common salt and strong sulphuric acid (oil of vitroil), made in pans over chaffing dishes placed in suitable positions, he completely purified the building and freed the town from infection. Though Morveau cannot claim the honour of first applying sulphate of soda (which is the residue of his fumigating mixture) to a useful purpose, yet he at least deserves the credit of first making it in a manner generally beneficial to the community at large.

John Rudolf Glauber was the discoverer of this salt, and in the full pride of his success, he fondly styled it his "sal mirabile"; he was born in the middle of the sixteenth century, and died in 1668, at a very advanced age, at Amsterdam. In his tract entitled "Miraculum Mundi," he fully describes his discovery, endowing it with all the properties of a universal medicine, and with an endless variety of virtues; its principal properties and mode of preparation are faithfully described, and it is still employed in medicine as a valuable laxative. In the spirit of his brother alchemists, Glauber indulged in no very sober dreams regarding the subject of his observations, but he never in his wildest moods contemplated the vast importance which this substance, still bearing his name, now assumes in the commerce of the world.

Glauber, of course, esteemed sea-salt as an element, and may almost be said to have made it his *pet* element, speaking of it in the following terms:—"It is the beginning and end of all things, and it increaseth and exalteth their powers and virtues; it is the true universal medicine;" but he cautions his readers that he does not by that, mean to make men immortal, for he is aware there is no medicine against death. The old philosopher was not only laborious and persevering to the greatest degree, but was also determined to give the world the benefit of his experience upon other than things of medicine and alchemy; he observes in the spirit of a sage, "nothing can extinguish Truth; it may be prest, but cannot be overcome—like the sun's light, it may be hidden, but never extinguished."*

This belief in the ultimate triumph of truth was sorely needed by philosophers, when they endeavoured to introduce their discoveries for the benefit of their fellow beings. Morveau experienced an instance of the too common prejudice against all that is not universally understood, when in 1776, he applied lightning conductors to the buildings of the academy of Dijon, and this aroused the indignation of the inhabitants at his "daring attempt to disarm the hand of the Supreme Being of its terrors,"—such being the language of the fanatics. The murmurs did not end in mere words, but an immense crowd of the zealots assembled for the purpose of destroying these objects of their displeasure, and were only turned from their intention by M. Maret (the secretary) assuring them that the whole of the marvellous virtue of the contrivance was contained in the gilded points, which were

* We almost fear that, in this instance, Glauber must be convicted of plagiarism, for it was said by a Roman (Quintus Fabius Maximus) long before the alchemist's time, "Truth is often eclipsed, but never extinguished."

relics sent expressly for that service from Rome by the "Holy Father." The old adage, "extremes meet," was, as our readers will remember, soon fully exemplified by the French nation, for in twenty years after this occurrence they not only overthrew the supremacy of the Pope, but actually declared themselves atheists.

The establishment of Morveau's soda manufactory, took place in consequence of the report made on the subject to the government of France, by Peter Joseph Macquer, who was born at Paris in 1718, and died in 1784; his name is often confounded with that of his brother, who was celebrated for his share in the literature of that time. P. J. Macquer was one of the most eminent of the French chemists, although strongly attached to the "phlogiston theory," which received its death-blow in his old days. His investigations of the compounds of arsenic acid, and of the acid of the then newly discovered Prussian blue, (prussic acid) redound most to his honour as a chemist. He was for many years an associate of the celebrated Beaumé, and is supposed to have been a descendant of a Scottish family whose fortune was sacrificed in the cause of the Stuarts.

Morveau was ennobled by Bonaparte in 1811, having been made director of the mint in 1799; his voice was the only dissenting one upon Sir Humphrey Davy's election as a "Corresponding Member of the Institute of France"—this arose from no personal feeling against the Englishman, to whom Morveau himself related the circumstance, but having promised his vote to another before knowing of Davy's application, he considered he was bound by his word.

The principal features of the present mode of manufacture were proposed by M. Leblanc, a French chemist, when in consequence of the suspension of the supplies of Spanish "barilla" during the revolution, the attention of scientific men had been specially drawn by the National Convention to the subject of "a certain means of rendering common salt available as a source of soda." Duhamel, of whom we have before spoken, had shown, in 1737, that the base of common salt is soda; but no use had been made of this discovery, although it had attracted the notice of the scientific world, and had even been called in question, particularly in a very elaborate dissertation published by John Henry Pott, who was born at Habberstadt in Prussia, in 1692. His knowledge must not be esteemed by this example (which was formally proved to be false by Margraaf) for it rests on a much broader basis. He was eminently learned and industrious, and the historical introductions to his essays show his great erudition; he was engaged by command of the king of Prussia, on the porcelain manufacture, and is supposed to have made thirty thousand experiments on that subject in six years, and thus laid the foundation of our knowledge of vitrification and the use of the blow-pipe in analysis; his essays on bismuth and zinc are also exceedingly valuable; yet, like many more, he was carried away by his prejudice, and endeavoured to cast doubt on a fact.

The first manufactory on the new plan was established at St. Denis in 1804, and though Leblanc was rewarded by the English government for his valuable discovery, yet he was neglected by that of his own country, and was left to die in an hospital. The enormously high duty which was levied in this country on salt, so late as 1823, effectually prevented the introduction of Leblanc's process; now, on the contrary, the kelp (sea-weed) shores of Scotland are all but valueless, and barilla is scarcely known in the market.

The old plan was to grow the "*salsola soda*" or the "*salicornia herbacea*" in the warm climates of Spain and the Mediterranean, and the "*fucus vesiculosus, serratus, digitatus, nodosus*" or other "fuci" in these more northerly climes. These alkali nurseries were of course placed on the sea shore, for there alone could the organic laboratories find sufficient salt to subject to the decomposing action of their energetic powers; the plants were burnt to ashes (forming "barilla" or "kelp") and the soda then dissolved from the insoluble matters, earths, sand, &c. by water, and the other soluble salts were afterwards separated by crystallization, the carbonate of soda varying from 2 to 20 per cent. of the ashes. In most striking contrast to this simple way of gathering a weed and washing its ashes, is the mode now followed to procure the alkali. First, we need common salt; for this, sea-water is evaporated, or a mine is sunk to the salt treasures in the earth; secondly, we require sulphuric acid, and to form this, iron pyrites must be brought from Cornwall or Ireland, or sulphur from Sicily, and nitrate of soda from the West Indies; lastly, we require lime, and this has to be quarried and carried perhaps hundreds of miles, and after all, the product has to be lixiviated and evaporated almost in the same manner as with kelp; and yet the apparently more complicated process is by far the cheaper of the two.

On entering those parts of a chemical factory where the soda process is carried on, the peculiar odour of muriatic acid is very perceptible, different from that diffused throughout the other buildings. The rock-salt is procured from the vast beds at Northwich in Cheshire. It is exposed to various processes, by which the chloride of sodium is converted into a sulphate of soda; then this into what is called ball soda; then this into the soda-ash employed in making soap and glass; and, lastly, this into the crystallized soda of the shops. Throughout these operations a succession of chemical changes ensues, not less remarkable than those in relation to sulphuric acid.

A given weight of salt is placed in a reverberatory furnace, that is, one in which the heat is echoed or reflected down from a concave roof upon the ingredients in the furnace. The salt is placed in a leaden pan within the furnace, and sulphuric acid is let down upon it through a leaden pipe in the roof of the furnace; or rather, the decomposition is first partially effected in an iron pan heated below, and then finished in the reverberatory furnace. The salt liquefies in the acid; and the heat which is brought to bear on the mixture soon causes a gaseous vapour to ascend. This gas is muriatic acid gas, containing, as one of its ingredients, the chlorine which had before been in the salt. The muriatic acid thus produced has often been a source of great trouble and expense to manufacturers. It is so deleterious, that if allowed to mingle with the atmosphere near the ground it would do great mischief; and hence the giant chimneys which such works exhibit, intended to carry off the gas to a great height. The gas, however, is now, in some of the factories, converted to a liquid form by an ingenious arrangement. All the furnaces discharge their muriatic acid gas into a bulky stone tower, about forty feet high by eight square. This tower is filled with coke, upon which a stream of water is constantly falling from above; and the gas, ascending the tower from the flues of the furnaces, meeting with an innumerable series of little streams of water trickling through the coke, becomes absorbed by the water, and falls again in the form of liquid muriatic acid. Thus a double advantage is gained by this plan: the muriatic acid is preserved in a form which renders it available for other departments of manufacture, and the atmosphere is saved from admixture with this most deleterious ingredient.

Meanwhile the salt has greatly altered its form. When the muriatic acid, by the application of heat, and by frequent stirring, has been removed from the furnace, the pasty mass which remains is sulphate of soda; and this sulphate is, at a particular period, drawn out of the furnace in a dry state.

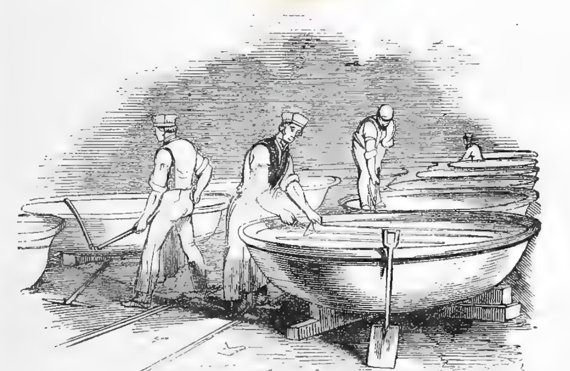
Then ensues another process, in which the chemical changes are too complex to be minutely detailed here, but whose general character may be pretty clearly explained. Furnaces of a peculiar form are provided, called *balling furnaces*, for the conversion of sulphate of soda into ball soda. The sulphate is mixed up with chalk or lime, and with coal, both ground very fine at a mill; and the whole are sifted to the state of powder before being put into the furnaces. When the mixed powder becomes heated, the coaly portion ignites at the surface; and when the mass begins to become liquid, a workman opens a door in the front of the furnace, introduces a rake or shovel, and turns the mass over, so as to expose a new surface uppermost. The door is again closed; the heat is allowed to act on the mass; and little jets of flame then begin to burst from it in every part. The workman next stirs and spreads the semi-fluid mass in every direction; and at length he removes it from the furnace. This is a very pretty operation

—at least it may be regarded so by a bystander, although it is rather a warm one to the workman himself. A low four-wheeled iron carriage is wheeled to the front of the furnace; on this carriage a shallow tray is placed, and into this tray the workman draws the semi-fluid mass from the furnace, by means of a kind of rake introduced at the door of the furnace. Shortly after the mass has fallen into the carriage, innumerable little jets of flame, called by the workmen "candles," burst out at its surface, and present a curious miniature illumination.

The semi-fluid mass solidifies in the iron tray, and comes out as a square mass, measuring about three feet square by one in thickness. This is called ball soda, or crude soda, or British barilla, and is the result of a curious series of chemical changes. The matters put into the furnace were coal, lime, and sulphate of soda; and these elements become so mingled and transferred by heat, that they appear, in the ball soda, chiefly as carbonate of soda and sulphuret of calcium.

Next ensues the separation of the two ingredients just named: the former valuable, and indeed the object of the whole operation; the latter valueless up to the present time. The ball soda is put into a cistern or tank, and covered with water, which is allowed to act on it for a considerable time, as a means of dissolving the carbonate of soda. The liquor is drawn off at the bottom, and more applied; and so on until all the carbonate has been dissolved. The point here aimed at is to dissolve all the carbonate and none of the sulphuret, for the latter would spoil the former. When this is accomplished, the liquor containing the dissolved carbonate is placed in an evaporating furnace, where, by the application of heat at the surface of the liquid, all the watery part is caused to evaporate; and the solid which remains is chiefly carbonate of soda, with a very small admixture of sulphur. By a further exposure to the heat of a furnace, this sulphur is driven off; and there remains a yellowish earthy substance, which is the common soda-ash or soda-salt, employed extensively in various manufactures. It contains about fifty per cent. of pure soda.

One more stage of improvement occurs before the soda is finally completed. For some purposes this earthy carbonate of soda will not suffice: it must be in a crystallized form; and to effect this crystallization another series of buildings, of processes, and of vessels is necessary. The soda-ash is again dissolved in water, again allowed to settle, and then boiled to a certain degree of consistency. Next ensues the crystallization, which is one of the most striking features in such operations. In a very large and cool building are numerous hemispherical cast-iron vessels from five to ten feet in diameter.



In these the liquor is placed, after having deposited its solid impurities; and here it remains until all that will crystallize has done so. It is a beautiful sight to see the large crystals radiating from the sides of the vessels towards the centre, and absorbing, as it were, into their substance more and more of the liquor, until only a little of this latter remains. After several days, the crystals are broken out from the vessels to be packed in barrels for the market; while the remaining liquid, called the "mother liquor," by a further process of evaporation, yields a very coarse kind of soda, fitted for some manufacturing purposes,—thus adding one more to the forms in which soda is presented by this interesting chain of processes.

One thing has yet to be noticed. What becomes of the solid impurities which occur in the process? This is one of the difficulties to which a chemical manufacturer is exposed. The sulphuret of calcium, the solid and useless ingredient in the ball soda, is a veritable source of trouble and expense. No profitable mode of applying it has yet been introduced: it cannot be melted and washed away, or heated and burned away; nor must it be thrown into any river. At one of the great soda-works, an enormous heap of 'waste' has accumulated, covering an area five or six acres in extent, and mounting to a height of thirty or fourty feet. Day by day is this heap increasing in extent; and more land has lately had to be purchased, to form a resting-place for heaps yet to accumulate. The earthen waste is not thrown here heedlessly: it is laid in a compact form, having a smooth and level surface at the top; and if the memory of present things were to pass away, future geologists might be puzzled to conjecture how such a mound got there. Not only the sulphuret of calcium from the soda process, but silica and ashes from other processes help to swell this heap.

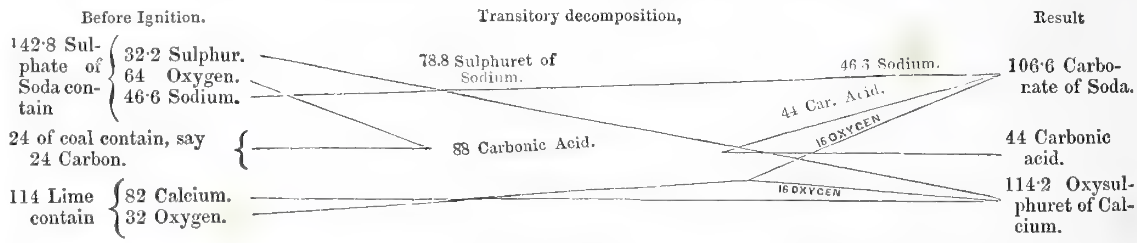
The rather confusing changes which common salt undergoes during the conversion into carbonate of soda, will be better understood if we consider the philosophy of the process. Common salt is a binary compound (consisting of only two elements) of the elementary substances, chlorine and sodium, the base of soda. Salt is called by chemists chloride of sodium (the two substances of which it is composed being chlorine, a gas, and sodium, a metal, whose rust or oxide, (compound of metal and oxygen,) is caustic or pure soda). Sulphuric acid, as we have before shown, contains sulphur, oxygen, and hydrogen; and when a mixture of common salt and sulphuric acid is heated, the hydrogen of the sulphuric acid combines with the chlorine of the salt to form a volatile substance called "spirits of salt," "muriatic" or "hydrochloric" acid gas; whilst a portion of the oxygen of the sulphuric acid unites with the metal (sodium) of the salt, forming its "oxide" or soda; the alkali thus produced, instantly unites with the compound of sulphur and oxygen remaining (dry or anhydrous sulphuric acid) and forms dry "Glauber's salt," "salt cake," or sulphate of soda. To put the change clearly before the mind, we refer the reader to the following diagram, which shows the conversion of 58·3 of common salt, and 49·1 sulphuric acid, into 36 of hydrochloric acid gas, and 71·4 of sulphate of soda:—

58·3 common salt contains	35 Chlorine 23·3 Sodium.	35 Chlorine and 1 Hydrogen form 36 Hydrochloric acid gas.
49·1 Sulphuric acid contains	40·1 Anhydrous Sulphuric acid. 1 Hydrogen. 8 Oxygen.	23·3 Sodium, 40·1 Sulphuric acid and 8 Oxygen form 71·4 of Sulphate of Soda.

To comprehend this thoroughly, the reader must bear in mind that in every portion of the common salt, however minute it may be, the chlorine is in *proportion* to the sodium as 35 to 23·3; and the concentrated sulphuric acid contains 40·1 of the so-called anhydrous acid to 9 of water, or (as water is composed of the two gases, oxygen and hydrogen) 40·1 of dry sulphuric acid to 1 of hydrogen and 8 of oxygen. When the mixture is made at a sufficiently high temperature, a new set of affinities or inclinations come into play; the chlorine of the common salt feels an inclination towards the hydrogen, and the sodium evinces a simultaneous desire towards the oxygen of the sulphuric acid; and as these desires of the chlorine and sodium are met with equal energy by the attractive parts of the acid, the union of the chlorine with the

hydrogen, and of the sodium with the oxygen and the dry sulphuric acid, take place at the same instant, and in precisely the same proportions under whatever circumstances they may be situated; thus, whenever hydrochloric acid gas is formed in a mixture of common salt and oil of vitriol, the sulphate of soda is formed simultaneously, and always in proportion to the former as 71.4 is to 36. There is no intermediate combination, neither is there by any chance a separation of an isolated element; but a similar affinity actuates all the elements *at once,* and neither the sodium, chlorine, hydrogen, oxygen, or sulphur, is ever extracted alone from the mixture referred to, but the result is uniformly hydrochloric acid gas and sulphate of soda; if more vitriol is added, it remains unaltered; if there is an insufficiency, the salt is not decomposed, and it is this unfailing *law of proportion* between cause and effect, which constitutes the foundation of the atomic theory propounded by the late Dr. Dalton.

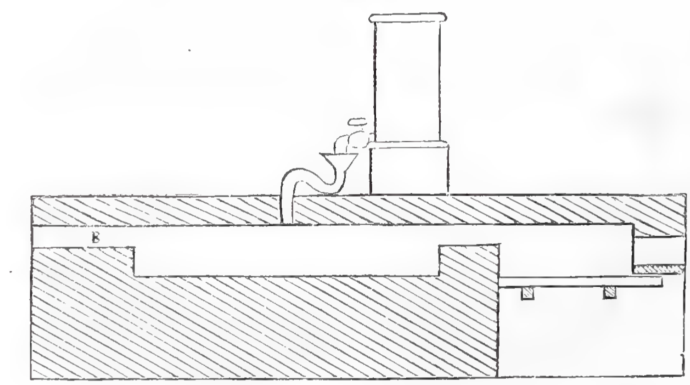
To the sulphate of soda or "salt cake" is added lime and coal; this mixture containing the elements sulphur, oxygen, sodium, calcium, and carbon, which are thus distributed: the sulphur, sodium, and part of the oxygen, are in the sulphate of soda: the calcium and the remainder of the oxygen in the lime (lime being an oxide or rust of the metal calcium) and the carbon in the coal. Sulphur readily combines with a metal forming a sulphuret; oxygen will combine with a metal to form an oxide, with sulphur to form various acid compounds (all however simple multiples of certain definite proportions) or with carbon, to form carbonic oxide or carbonic acid, the former containing twice as much carbon as the latter. Carbon, when ignited with any compound containing oxygen, decomposes it and appropriates a portion of the oxygen. The mixture referred to, being melted or "fluxed" in a suitable reverberatory furnace, the carbon of the coal combines with the oxygen of the sulphate of soda and leaves the sulphur and the metal sodium combined as a sulphuret of sodium, but the lime decomposes this compound, giving rise to oxide of sodium or caustic soda and a compound of sulphuret of calcium and lime, sometimes called oxysulphuret of calcium. As all the decompositions are proceeding at once, a great portion of the carbonic acid (formed by the union of the carbon with the oxygen of the sulphate of soda) combines with the caustic soda to form carbonate of soda, these two substances having a strong mutual affinity. We subjoin a diagram of the *theory* of the decompositions, the results of which are realised in practice to a very great extent by adopting suitable precautions; but the number of elements present, and their nearly balanced affinity for various substances and multiples of proportions, render this part of the process liable to considerable variation:



The mass thus obtained is termed "black ash," and is generally vitiated, from the presence of sulphuret of sodium, sulphate of soda, uncombined carbon, caustic soda, and many other compounds which arise from the various causes already pointed out.

Though the decomposition of the sulphate of soda is from economical considerations always effected in the presence of lime, yet the same result would be obtained by first converting the sulphate into a sulphuret, and then calcining it with carbonate of lime (limestone or chalk). Sulphuret of calcium is soluble in water, and if the solution be added to a solution of carbonate of soda, carbonate of lime is precipitated by double decomposition, and sulphuret of sodium remains in solution. But, fortunately for the success of this manufacture, sulphuret of calcium combines with lime, and is then *in*soluble in water; this combination is sometimes called the oxysulphuret of calcium, or more tersely by alkali manufacturers, "soda waste;" it is stable in water at ordinary temperatures, but at a heat considerably less than the boiling point it is decomposed, if carbonate of soda be present, thus preventing the use of hot water in the lixiviation of the "black ash." Having thus described the theory of the changes, we will give a short account of the furnaces and other apparatus employed, and in the next chapter we shall notice some of the attempted or proposed improvements in the manufacture.

Fig. 1.



The sulphate of soda is commonly prepared in reverberatory furnaces, having flat bottoms or "beds," carefully made of firebricks, set on end in clay; on the top of the furnace is a tube or vessel of lead, with a pipe through the crown; from this vessel the sulphuric acid is measured upon a known weight or "charge" of salt; the mixture is then allowed to "work" at a moderately elevated temperature until the salt is nearly all "cut" (decomposed); the heat being then raised,

the mass is dexterously tossed about with an iron paddle, to allow of the perfect extrication of the muriatic acid gas; when dry it is withdrawn, and whilst hot, the "salt cake" is of a beautiful yellow colour, being allowed to cool till it becomes snowy white, and this part of the process is completed.

Fig. 2.

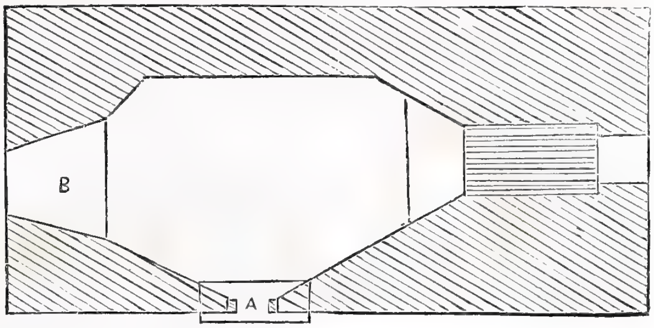
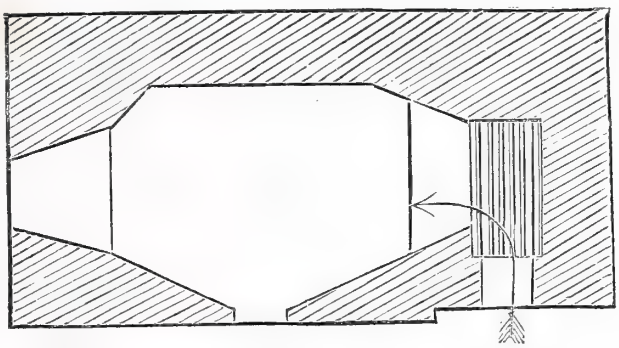


Fig. 1 is a section of an ordinary reverberatory furnace employed for this purpose, fig. 2 being a sectional plan. Very great care is required in laying the "bed," for any leakage of the acid is not only so much loss, but soon destroys the building by its corrosive action. Through the opening, A, the salt is introduced, and the finished salt cake

Fig. 3



withdrawn; a dam of salt is made at this mouth when the acid is introduced, and is maintained so long as the materials are fluid; the smoke and muriatic acid gas pass off by the flue B.

In the construction of reverberatory furnaces, a great saving of fuel is effected by placing the grates in the position shown in Fig. 3, at right angles to the length of the furnace. The air drawn over the fire, when the draught is at the end, as in figs. 1 and 2, is heated in its passage, and mixing in that state with the smoke and unconsumed gas, ensures their more perfect combustion; in fig. 3, the air (as shown by the arrow) turns round the corner immediately, thus cooling the near side of the furnace and only partially mixing with the smoke. The mouths of the grate rooms are not provided with doors, but have broad dead plates, and are stopped with "slack" (small coal), thus increasing the body of fuel, and serving as most excellent nonconductors and *useful* absorbers of heat.

The muriatic acid gas is the alkali manufacturer's bugbear, proving an intolerable nuisance to the neighbourhood, if allowed to escape into the atmosphere, and being exceedingly troublesome to condense *perfectly*. When "salt cake" is made in such furnaces as those represented, the evolved muriatic acid gas is so intermingled with air and smoke, that its complete separation is nearly if not quite impossible. The only method is by passing the mixed gases over an extended surface of cold water; but this if carried on sufficiently to condense the whole of the acid, would, by cooling the air, destroy the draught; in practice, therefore, it can only partially succeed; the greater part of the acid may be withdrawn and the nuisance thus materially lessened, but some must still escape and prove to the neighbouring farmers annoyance, that the remedy is ineffectual.

A patent has been secured by J. C. Gamble, for a mode of more perfectly decomposing the salt, and also of condensing the whole of the muriatic acid in a fit state for use, the acid condensed by the old method being too weak for any practical purpose, and is only a waste product very troublesome to be rid of. The patent has been running eight or nine years, and is extensively employed in Glasgow, Newcastle, Birmingham, St. Helens, &c.

The furnace employed for this purpose consists mainly of two adjoining parts, a decomposing and a roasting furnace, both heated by *external* flues, and being, in fact, large retorts. The decomposing furnace or retort is in shape somewhat like two saucers placed mouth to mouth, and is made of iron, it being found that muriatic and sulphuric acids, when *concentrated* and *hot*, act very slowly on that metal. In this iron pan furnace (moderately heated), the mixture of salt and sulphuric acid is made, and allowed to ferment or "work"—the muriatic acid is thus kept separate from the smoke, and can be cooled to any extent that may be necessary, without injury to the draught, and the greater regularity of the heat ensures more perfect decomposition. The principal part of the muriatic acid is extricated whilst in this furnace, and when the mass is partially dry or "pasty," it is pushed through an opening in the wall between the two furnaces into the roasting furnace, which is built of brick and is heated to bright redness by flues running under and over it; the "salt cake" is here perfectly dried, the muriatic acid gas being kept from the smoke, as in the decomposing furnace.

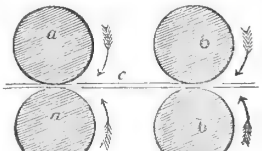
THE MACHINERY OF THE COTTON MANUFACTURE.

CHAPTER V.

THE DRAWING FRAME—MR. MASON'S FORM.

We now proceed to the description of the "drawing machine." The nature of the process will be easily understood from an examination of the following:—Let two pairs of rollers, *a a*, *b b*, fig. 1, revolve at the same rate, any sliver of cotton in *c* will be uniformly taken up by *b b*, while let out by *a a*; but suppose that *b b* revolve much faster than *a a*, the consequence will be, that the sliver will be taken up so much faster by *b b* than *a a* give it out, and an elongation will be the result, tending to separate the sliver somewhere between the two pairs of rollers. By adjusting the relative speed of these, the fibres constituting the sliver can be stretched out as divided; thus adding to their parallelization. In the drawing frame there are three sets of rollers, the difference of speed being between the first and third. A set of slivers from the carding engine is passed through the trumpet mouth attached to the drawing frame, and passed between the rollers, and delivered to a cone. Supposing eight slivers are passed through the rollers, it is evident that the chances of the parallelization of the combined slivers are increased eight times. By taking eight of these slivers, and again passing them through the drawing frame, and combining them into one, the chances of equallization of fibre are now increased sixty-four times. By this process of "drawing" and "doubling" being carried on to a great extent, the fibres are at last laid parallel to one another.

Fig. 1.

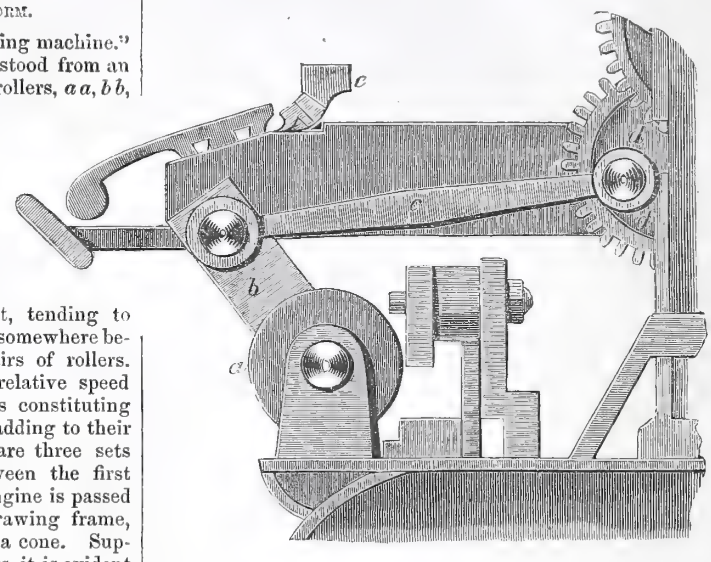


In the plates connected with this series of papers, will be found one which gives an end, back, and front elevation, and a section of Mr. Mason's (of Rochdale) form of "drawing frame." The sliver from the cone, *p*, of the carding engine, is delivered to the rollers, *h h*, the lower of which are fluted as at *m m* in the front elevation, the upper ones being covered with leather. A board, *g*, the under side of which is covered with rough flannel, is placed in contact with the rollers, and serves to keep them free from all adhering fibres, these adhering to the flannel. The sliver passes from the drawing roller to the "presser plate," *t t*; this has a revolving motion given to it by appropriate gearing. The sliver is coiled ultimately within the cone, *v v*; this revolving, the motion being given to it by the shaft, *n*.

Should any of the slivers break in their passage from the can of the carding engine to the drawing rollers, it is necessary to stop the motion of the whole of the rollers in the whole length of drawing frame, in order that all the cones on the other side shall have a like quantity of material in each. This stoppage of the rollers is effected by the simple mechanism known as "Houldsworth's stop motion." A lying shaft, *a a*, fig. 2, is made to oscillate, or have an alternate motion from left to right, by means of the crank, *b b*, actuated by the connecting-rod, *c c*, one end of which is jointed to a stud in the face of the wheel, *d d*. A brass lever, *e e*, is nicely balanced at the side of the frame. "The top part of this lever is furnished with a flat groove, over which the sliver passes; so long as the connection is kept up between the rollers, *h*, and can, *p*, (see the plate,) by means of the sliver, the friction of the passing sliver keeps up the head of the lever, *e e*, fig. 2, but as soon as the sliver breaks, the lever drops, the hook at its lower end catching the attenuating lever, *b b*, fig. 2; this throws forward a fork lever, which passes the driving belt from the fast to the loose pulley. The whole range of rollers is thus stopped until the attendant pieces up the broken end or ends."

In the plate, on the end elevation, *aa* is the framing; *bb*, the driving pulley on main shaft, *b′ b′*. The motion is given to the speed pulleys, *c*, in the standard, *d*, by the strap, *e* (front elevation). Bevel gearing, *s s*, drives the presser plates. Vertical motion is given to the cans, *v v*, by the lying shaft, *n n*, driven by the bevel gearing on the vertical shaft, *o o*, which

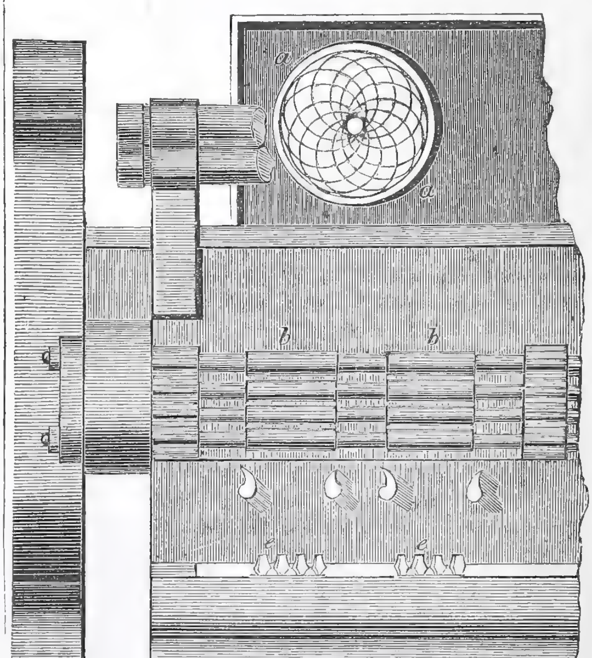
Fig. 2.



in its turn derives motion from the presser-wheel driving shaft by the bevil wheels, *s s*. The necessary pressure is given to the sliver in its passage through the rollers by weights, *o o*.

Fig. 3 is an enlarged sketch of part of the "plan" of the

Fig. 3

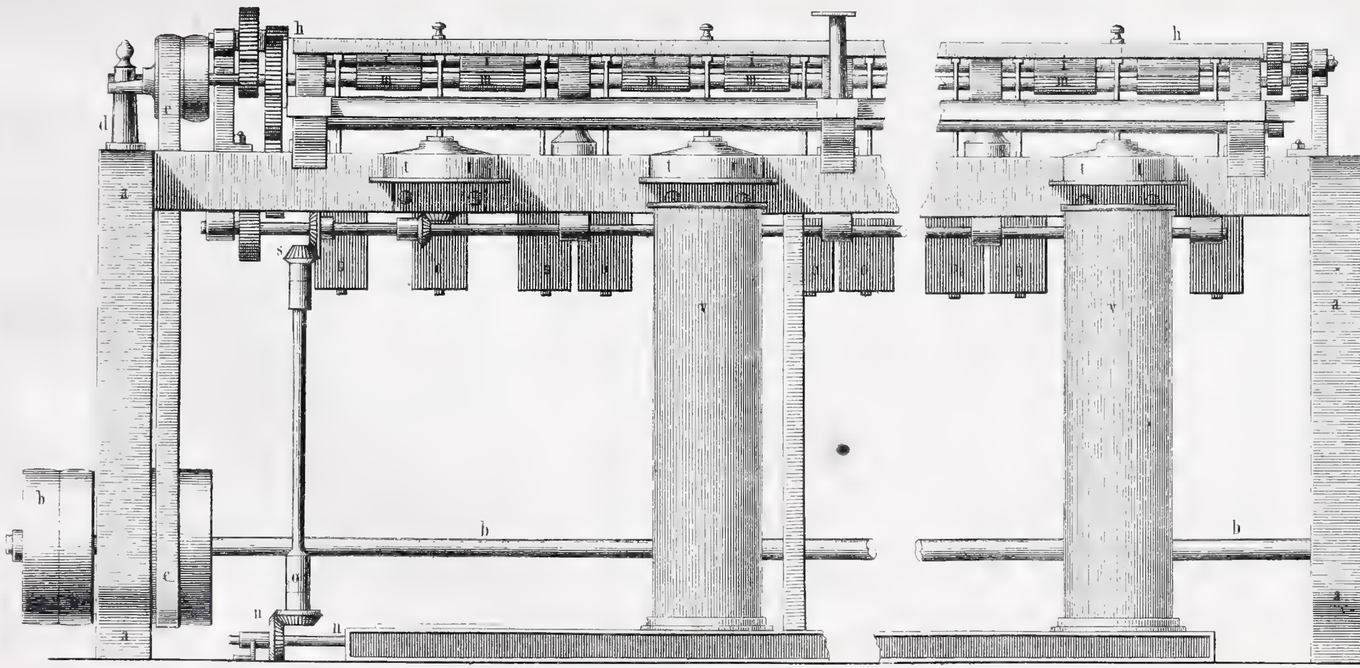


drawing frame; *a a*, the can receiving eight of the carding engine slivers; *e e*, the levers of the "stop motion;" *b b*, the two sets of standing rollers.

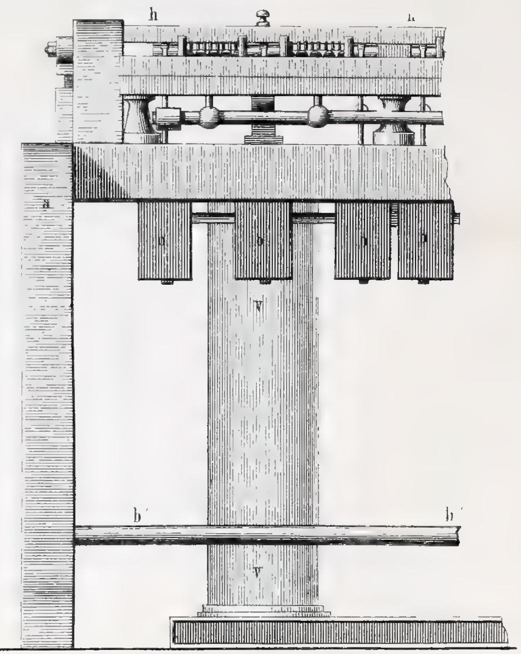
In our next we shall proceed to describe the roving frame, or bobbin and fly frame.

COTTON DRAWING FRAME

FRONT ELEVATION



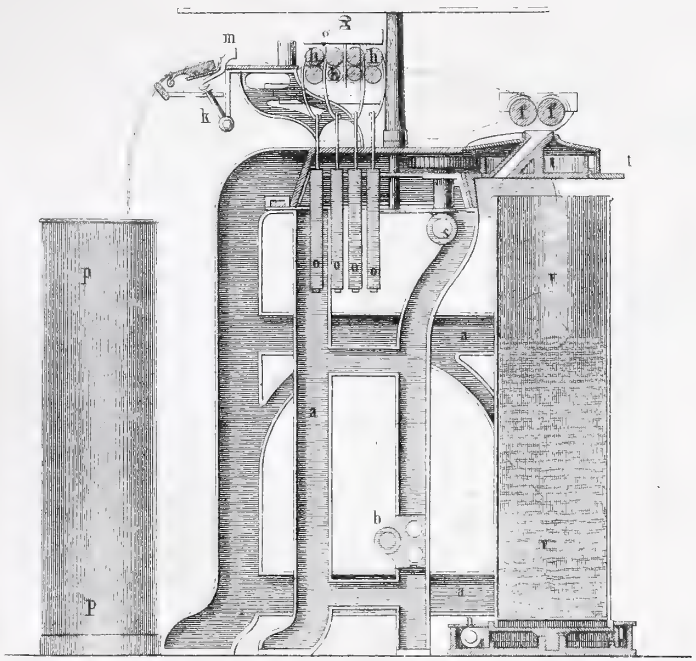
BACK ELEVATION



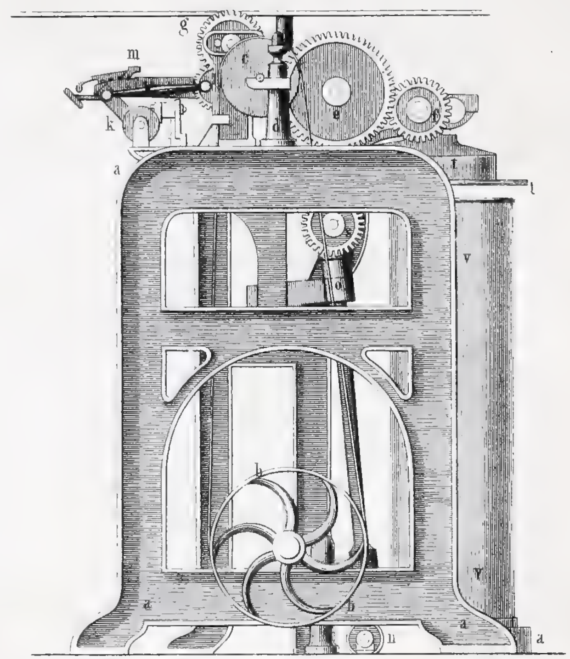
COTTON DRAWING FRAME.

SCALE ¾ INCH=1 FOOT

SECTION



END ELEVATION



THEORY AND PRACTICE OF NAVIGATION.

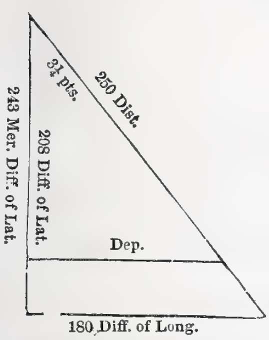
CHAPTER IV.

I.—MERCATOR'S SAILING.

This sailing is so named after the inventor, Gerrard Mercator, born at Ruremond, Upper Guelderland, in 1512, he having observed the errors of the charts in use at that time, and the trouble which attended them. He was the first projector of the chart bearing his name. In this projection the meridians are parallel to each other, but the degrees of latitude are enlarged towards each pole, in the same proportion as the degrees of longitude diminish on the globe. This chart was greatly improved by Mr. Edward Wright, of Caius College, Cambridge. Mr. Wright constructed a table of meridional parts, for the division of the meridian according to this principle, by the addition of the natural secants of each minute of latitude, in place of taking the sum of the secants of each. It is generally inferred that Mercator was not acquainted with the true principles of projection.

This is a very easy, accurate, and expeditious method of resolving the various problems in navigation.

The Latitudes and Longitudes of two places given, to find the Course and Distance between them.



Example. — A ship sailed from latitude 32° 40′ N., and longitude 9° 12′ W., to latitude 29° 12′ N., and longitude 12° 12′ W. What is her direct course and distance?

Latitude left, - -	32° 40′ N.
Latitude in - -	29° 12′ N.
Difference of latitude,	3° 28′
	60
In miles, - -	208

Latitude left, Mercator's parts, - - - -	2076
Latitude in, do., - - - -	1833
Mercator's difference of latitude, - -	243
Longitude left, - - - - - -	9° 12′ W.
Longitude in - - - - - -	12° 12′ W.
Difference of longitude, - - - - -	3°
	60
In miles, - - - - - - -	180

To find the Course.

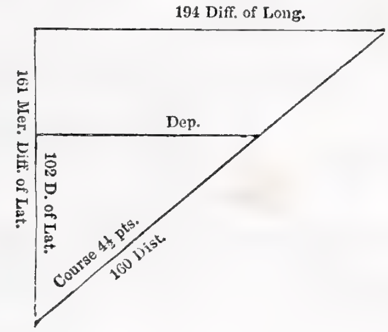
As Mercator's difference of latitude 243, -	2·38561
Is to difference of longitude 180, - - -	2·25527
So is radius, - - - - - - -	10·00000
	12·25527
	2·38561
To tangent of course, 36° 33′, 3¼ points, -	9 86966

To find the Distance.

As radius, - - - - - - - -	10·00000
Is to secant of course, 3¼ points, - - -	10·09517
So is proportional difference of latitude 208, -	2·31806
	12·41323
	10 00000
To distance, 259, - - - - -	= 2·41323

Given one Latitude, Course, and Distance, to find the Difference of Latitude and Longitude.

Example.—Suppose a ship sailed from latitude 51° 28′ N., and longitude 30° 25′ W., 160 miles, between south and west, upon a course of 50° 20′. What is her present latitude and longitude?



To find the Difference of Latitude.

As radius, - - - - - - -	10·00000
Is to cosine of course, 4½ points, nearly - -	9·80504
So is the distance, 160, - - - - -	2·20412
	12·00916
	10·00000
To difference of latitude 102, - -	= 2·00916

To find the Latitude in.

Latitude left. - - - - - - -	51° 28′ N.
Difference of latitude $\frac{102}{60}$, - - - - -	1° 42′ S.
Latitude in - - - - - - -	49° 46′ N.
Latitude left, Mercator's parts, - - - - -	3614
Latitude in, do., - - - - -	3453
Mercator's difference of latitude, - - - - -	161

To find the Difference of Longitude.

As radius, - - - - - - - -	10·00000
Is to tangent of course, 50° 20′, 4½ points, -	10 08132
So is Mercator's difference of latitude 161, -	2·20683
	12·28815
	10·00000
To difference of longitude 194, - -	= 2·28815

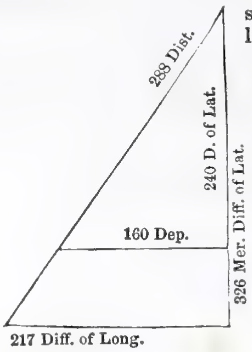
To find the Longitude in.

Longitude left, - - - - - - -	30° 25′ W.
Difference of longitude, $\frac{194}{60}$, - - - -	3° 14′ W.
Longitude in - - - - - - - -	33° 39′ W.

Both Latitudes and Departure given, to find the Course, Distance, and Difference of Longitude.

Example.—Suppose a ship sails from latitude 44° 30′ N., and longitude 8° 6′ W., between south and west, until she arrives in

latitude 40° 30′ N., and finds she has made 160 miles of departure. What is the course she has steered, the distance run, and the longitude come to?



Latitude left, - - -	44° 30′ N.
Latitude in - - -	40° 30′ N.
Difference of latitude,	4°
	60
In miles, - - - -	240
Latitude left, Mercator's parts,	2988
Latitude in, do.,	2662
Mercator's difference of latitude, - - - - - -	326

To find the Course.

As difference of latitude 240, - - - -	2·38021
Is to departure, 160, - - - - - -	2·20412
So is radius, - - - - - - -	10·00000
	12·20412
	2·38021
To tangent of course, 33° 42′, 3 points, - -	9·82391

To find the Distance.

As sine of course, 3 points, - - - -	9·74417
Is to radius, - - - - - - -	10·00000
So is departure, 160, - - - - - -	2·20412
	12·20412
	9·74417
To the distance, 288·3, - - -	= 2·45995

To find the Difference of Longitude.

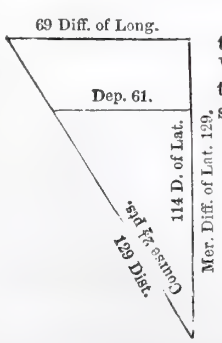
As radius, - - - - - - -	10·00000
Is to tangent of course, 3 points, - - -	9·82391
So is Mercator's difference of latitude 326, -	2·51322
	12·33713
	10·00000
To difference of longitude 217, - -	= 2·33713

To find the Longitude in.

Longitude left, - - - - - - -	8° 6′ W.
Difference of longitude, $\frac{217}{60}$, - - -	3° 37′ W.
Longitude, - - - - - - -	11° 43′ W.

Both Latitudes and Course given, to find the Departure, Distance, and Difference of Longitude.

Example.—A ship sailed from latitude 27° 10′ N., and longitude 12° 20′ W.N.N.E. ½E., and finds she is in latitude 29° 4′ N. What is the distance sailed, and longitude come to?



Latitude left, - - - -	27° 10′ N.
Latitude in - - - - -	29° 4′ N.
Difference of latitude, - -	1° 54′
	60
In miles, - - - - -	114
Latitude left, Mercator's parts, -	1695
Latitude in, do., -	1824
Mercator's difference of latitude,	129

To find the Distance.

As cosine of course, 2½ points, - - -	9·94546
Is to radius, - - - - - - - -	10·00000
So is difference of latitude 114, - - -	2·05690
	12·05690
	9·94546
To distance, 129, - - - - - -	2·11144

To find the Difference of Longitude.

As radius, - - - - - - - -	10·00000
Is to tangent of course, 2½ points, - -	9·72780
So is Mercator's difference of latitude 129, -	2·11059
	11·83839
	10·00000
To difference of longitude 69, - -	= 1·83839

To find the Departure.

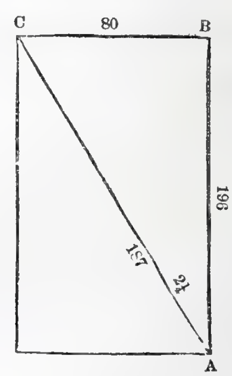
As radius, - - - - - - - -	10·00000
Is to tangent of course, 2½ points, - -	9·72780
So is difference of latitude 114, - - -	2·05690
	11·78470
	10·00000
To departure, 61, - - - - -	= 1·78470

To find the Longitude in.

Longitude left, - - - - - -	12° 20′ W.
Difference of longitude, $\frac{69}{60}$, - - -	1° 9′ E.
Longitude in - - - - - - -	11° 11′

II.—WIND AND CURRENT SAILING.

Example 1.—A ship sails, by compass, directly north, 169 miles in 20 hours, in a current setting west 80 miles in the same time. What is the course and distance sailed?



A B = 169
B C = 80
Course, B A C = 2¼ points.

To find the Course.

As apparent distance, 169, - -	2·22789
Is to the current, 80,	1·90309
So is radius, - -	10·00000
	11·90309
	2·22789
To tangent of course, 2¼ points,	= 9·67520

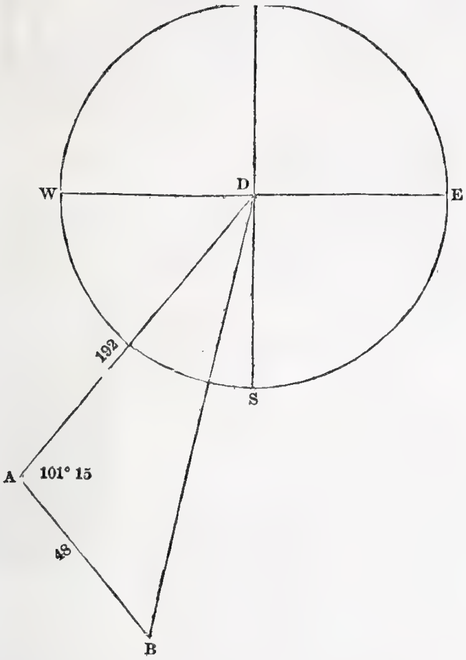
To find the Distance.

As the sine of course, 2¼ points, - - -	9·63099
Is to radius, - - - - - - -	10·00000
So is the departure, 80, - - - - -	1·90309
	11·90309
	9·63099
To the distance, 187, - - - - -	= 2·27210

Solution by the Mathematical Rule.

Set F to 169 on B, the apparent distance; move C till it cuts 80 on F, and 187, the true distance, will be given on C, and $2\frac{1}{4}$ points will be given on the quadrant, A, as the course.

Example 2.—Suppose a ship sails S.S.W., at the rate of 8 knots an hour, in a current setting S.E. by E., 2 miles an hour.



What is her course, and distance made good in 24 hours?

In the triangle, A D B, the side, A D, equals $24 \times 8 = 192$; the side, A B, $24 \times 2 = 48$; and the included angle, D A B, 9 points, or 101° 15′; to find the angles, B and D, and the side, D B, or distance.

To find the Angles.

Side, A D,	192
Side, A B,	48 sub.
Sum,	240
Difference,	144

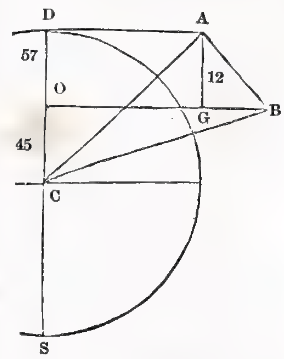
As the sum of D A + A B = 240,		2·38021
Is to the difference of D A — A B = 144,		2·15836
So is tangent of half sum of angles, 39° 22′,		9·91404
		12·07240
		2·38021
To tangent of half difference of angles,	26° 12′ =	9·69219
Half sum of angles,	39° 22′	
	65° 34′ =	Angle A B D
	13° 10′ =	" A D B
	22° 30′ =	" A D S
$\frac{3}{4}$ points — course =	8° 20′ =	" B D S
	S $\frac{3}{4}$W	

	180°
Angle A,	101° 15′
Sum of angles B and D,	78° 45′
Half sum,	39° 22′

To find the Distance D B.

As the sine of B, 65° 34′,	9·95925
Is to the sine of A, 101° 15′,	9·99157
So is the distance A C, 192,	2·28330
	12·27487
	9·95925
To distance D B, 206° 8′ =	2·31562

Example 3.—A ship sailed from latitude 12° 15′ N. 24 hours, in a current setting N.W. $\frac{3}{4}$N., and is in latitude 13° N. by account, having made 40 miles of easting; but the latitude by observation is 13° 12′. What is the course and distance made good, and the drift of the current?



Latitude left,	12° 15′ N.
Latitude by account,	13° 0′ N.
Dif. of lat. by account, 45 miles.	
Latitude left,	12° 15′ N
Lat. by observation,	13° 12′ N.
Difference of latitude by observation,	57 miles.

Difference of latitude by observation,	57 miles, D C
Do. by account,	45 " O C
Difference of latitude between latitude of account and latitude of observation,	12 miles.

Draw A G perpendicular to O B; so, in the triangle, B G A, are given A G = 12 miles, and the angle, B A G = $3\frac{3}{4}$ points = N.W. $\frac{3}{4}$N., 42° 11′, to find A B and B G.

To find the Drift of Current, A B.

As radius,	10·00000
Is to secant of B A G, $3\frac{3}{4}$ points,	10·13021
So is A G, 12,	1·07918
	11·20939
	10·00000
To drift of current, A B, 16,	= 1·20939
Rate of current, $\frac{16}{24} = \frac{4}{6} =$ 0·6 per hour.	

To find B G.

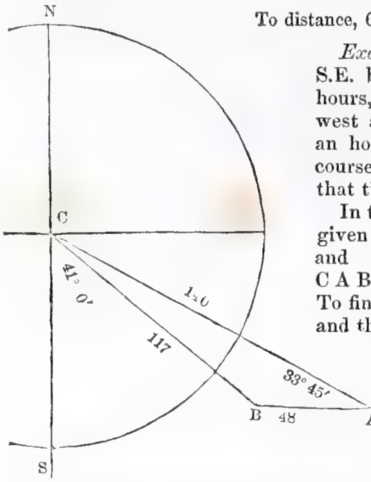
As radius,	10·00000
Is to tangent of B A G, $3\frac{3}{4}$ points,	9·95729
So is A G, 12,	1·07918
	11·03647
	10·00000
To B G, 10° 8′ =	1·03647
Departure by account, O B,	40° 0′
True departure,	29° 8′ A D.

To find the Course.

As difference of latitude 57,	1·75587
Is to departure, 29° 8′,	1·47422
So is radius,	10·00000
	11·47422
	1·75587
To tangent of course, 27° 36′, A C D,	= 9·71835

To find the Distance, A C.

As radius,	10·00000
Is to secant of course, 27° 36′,	10·05247
So is difference of latitude, 57,	1·75587
	11·80834
	10·00000
To distance, 64° 3′,	= 1·80834



Example 4.—A ship sailed S.E. by E. 140 miles in 24 hours, in a current that sets west at the rate of 2 miles an hour. What is her true course and distance sailed in that time?

In the triangle, A B C, are given C A, 140; A B, 48; and the included angle, C A B, 33° 45′, or 3 points. To find the angles, B and C, and the side, C B.

Side, A C,	140
Side, A B,	48
A Sum,	188
Difference,	92

As sum of A C + A B = 188,	2·27416
Is to the difference of A C — A B = 92,	1·96379
So is tangent of half the sum of angles, 73° 7′,	10·51806
	12·48185
	2·27416
To tangent of half difference of angles, 58° 12′ =	10·20769
Half sum of angles,	73° 7′

131° 19 = Angle A B C.

14° 55′ = " A C B.
56° 15′ = " A C S.

41° 20′ = " B C S.
Course.

	180°
Angle A,	= 33° 45′
Sum of angles, B and C,	146° 15′
Half sum,	73° 7′

To find the Distance, C B.

As sine of B, 131° 19′,	9·81969
Is to sine of A, 33° 45′,	9·74474
So is distance, A C, 140,	2·14613
	11·89087
	9·81969
To the true distance, 117,	= 2·07118

THE MACHINERY OF THE COTTON MANUFACTURE.

CHAPTER VI.

The work to be performed by the machine next in sequence—the "roving frame"—is of two kinds: the drawing of the sliver by passing it through the drawing rollers, and, secondly, giving the drawn sliver a twist, and coiling it thus twisted round a bobbin. In some forms of roving frames, the cotton is wound round a bobbin of the form as shown in fig. 1, so that an equality of cotton sliver is placed uniformly throughout. In other forms of roving frames, the cotton is wound upon a tube or wooden barrel without ends, and made to assume the form of the cylinder, *a a*, with conical ends, as in fig. 2. The bobbins thus formed are known as "presser bobbins," the cotton being compressed on the bobbins by the action of a spring, *g g*, which keeps the finger, *f*, pressed against the surface of the bobbin, delivering a much greater quantity than in the bobbin of the form of fig. 1. Fig. 3 is a plan of this form, known as "Seed's Centrifugal Presser." Dr. Ure instituted some experiments to test the relative quantities of cotton taken in by presser and the ordinary form of bobbins. Where fourteen ounces were put on by the "spring press," seven and a half only were laid on by the ordinary flyer and bobbin.

Fig. 1.

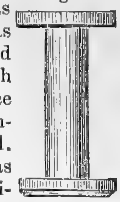
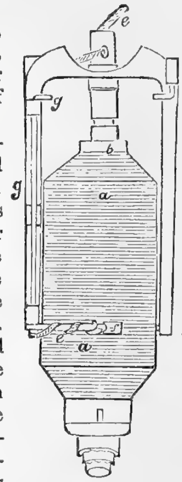


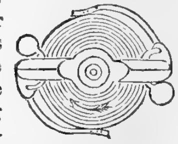
Fig. 2.



In the roving frame now to be described, the motions are divisible into two classes, the uniform and the variable, the latter being that of the bobbin, and the former of the drawing rollers and spindles.

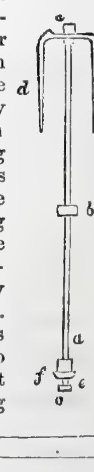
The formation of the cord, and the delivering of it to the bobbin, are produced by the following means. A vertical spindle, *a a*, fig. 4, revolves in the stop at *c*, and is supported at the bearing at *b*. A fork or flyer, *d*, is fixed at the upper end of the spindle, but is easily removeable. The prong of this fork is hollow, to admit of the cotton sliver passing down to its extremity. At the foot of the spindle a small bevil wheel is placed, at such a distance from the stop as to admit of a driving wheel, *e*, which gives motion to the spindle. Round the spindle, and in the same direction of motion, but at a different speed, a bobbin revolves, as in fig. 5. The motion of this is therefore independent of that of the spindle. The bobbins receive their motion by bevil gearing, *a b*, fig. 5, the bearing of which is upon the "copping rail," *a*. The twist of the sliver is produced by the revolution of the spindle round the bobbin, while the winding on is performed by the difference between the speed of the bobbin and that of the spindle. At first starting, the speed of the bobbin is greater than that of the spindle and fly; but, as its diameter increases, the speed has to be reduced in order to enable it to take on the quantity of sliver given out by the drawing rollers, which, as before mentioned, is uniform at all times. A due understanding of this point, and its influence on the important mechanism of the "frame," is so essential to a proper knowledge of its operation, that we purpose going further into its consideration.

Fig. 3.



The quantity of sliver given out by the drawing rollers is, in all cases, uniform. On the supposition that the circumference of the empty bobbin is equal to that of the drawing rollers, it is evident that one revolution of the bobbin will take up just as much sliver as the rollers deliver. But as each layer of cotton is delivered by the uniform motion of the spindle and fly, the diameter of the bobbin necessarily increases, and in this way the relative condition of the diameter of the bobbin to that of the drawing rollers is continually changing. Further, let us suppose that the speed of the bobbin is 8, that of the spindles 4, the circumference of the bobbin being 3. On first starting, the revolution of the spindle delivers the cotton completely round the circumference of the bobbin; the length of this quantity being 3, or equal to the circumference of the bobbin. By the operation of the machine, the cotton is wound on till the circumference of the bobbin is so increased, that it is no longer represented by 3, but by 6 or 9. The length of sliver given out being

Fig. 4.



uniform, it is clear that it cannot be delivered round a space of three times its length in the same time as before. This can only be done by increasing the speed of the spindle and fly, so as to outstrip that of the bobbin; or by decreasing the speed of the bobb'n, so that the spindle may be able to deliver the cotton to its increased surface. The latter is the operation performed. The relative position of the bobbin, the speed of the spindle, and the quantity of cotton to be wound on, are very familiarly explained in an article in the *Artizan*, which we now present to the reader:—"Suppose a large wheel to revolve in vertical bearings, and that a boy is charged with the task of

Fig. 5.

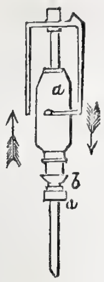
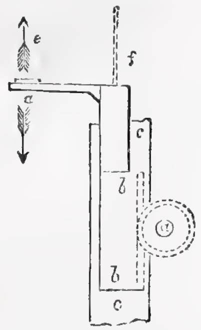


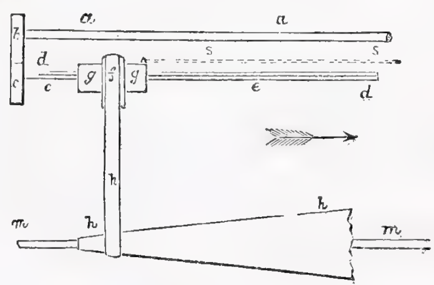
Fig 6.



winding on a certain length of cord, given out uniformly every minute. If the speed of the large wheel was to remain uniform, it is clear that, as its diameter increased, the boy would require to run faster, this increase of speed being proportioned to the increase of the diameter of the wheel, just as the horse near the circumference of a gin walks fast, while his neighbour near the centre walks slowly; or the sailors at the ends of the levers of the windlass have to run merrily, whilst those near the centre take it very easily. If, however, it was essential that the speed of the boy, like that of the quantity of cord given out to him every minute, should be uniform, the speed of the wheel would have to be decreased, or the result would be, either that the cord would be broken, or be pulled out of the boy's grasp. But the diameter of the wheel increasing with every layer of cord laid on its surface, its speed would have to be correspondingly altered for every revolution. This is just what has to be done in the roving machine. The speed of the bobbins has to be adjusted to the exact rate of increase of their diameters, and the traverse of the copping rail in like proportion." What is meant by the traverse of the copping rail, we have now to explain. If the delivering finger of the fly always delivered the cotton exactly at the same level with reference to the surface of the bobbin, the consequence would be, that its diameter would be constantly increasing at one place only, while the other parts of the bobbin would be receiving none at all. To distribute the cotton equally over the whole surface of bobbin, is a matter of much importance. To do so, one of two things is necessary: to make the bobbin stationary, making the delivery finger move up and down over its surface; or to make the finger remain always at one level, and the bobbin to move up and down the spindle. This latter is the method adopted. To effect it, the bobbins rest upon a long rail, termed the "copping rail," which has an up-and-down motion given to it by the following mechanism. A small pinion is fixed at the end of a horizontal shaft, and takes into a vertical rack, *b b*, fig. 6, working in a slide, and at the upper end of which is attached the arm of the copping rail, *d*, in which the bobbins rest, and to which the driving gear is attached. An alternate up-and-down motion is given to the rack, *b b*, by the pinion, *a*, alternately moving from right to left, and *vice versa*, this change of direction of motion being effected by the contrivance known as the "mangle wheel" motion (see Table of Mechanical Movements), of which *a* is the shaft. As the rack moves up and down, the bobbins have a corresponding movement on the spindle, so that each portion of the surface is presented to the delivering finger. A weight attached to the end of a chain, *f*, passing over pulleys, relieves the strain on the teeth of the rack and pinion, *a*, *b b*. The connection of this part of the mechanism with that which regulates the speed of the bobbins will now be traced. By referring to the Tables of Mechanical Movements, the reader will find an explanation of the "cone pulleys," by which the relative speed of shafts is changed from slow to fast, and *vice versa*. This contrivance is adopted in the roving frame as follows:—

Let *a a*, fig. 7, be the main driving shaft of the "frame," having a spur-wheel, *b*, at one extremity, driving another, *c*, fixed on a second shaft, *d d*. The speed of the two shafts is equal. The motions are all derivable from the shaft, *d d*. A moveable box, *g*, is allowed to slide along the shaft, *d d*, having at the same time a circular motion corresponding to that of the shaft. This is effected by a rib or feather made in the shaft, taking into a slot or groove made in the interior of the box, *g*. A pulley is made at one end of this box, and the belt passes over it, and also over that of the cone pulley, *h h*, revolving with the shaft, *m m*. The belt being made of length sufficient to embrace the large end of the cone as well as the small one, is kept stretched, while passing over the small end, by a weight passing over a pulley revolving with a shaft, supported by two arms projecting from the moveable box, *g*. While the belt passes towards the large end of the cone pulley the weight is raised, while passing to the small end it falls. Thus, in all cases, the belt is kept in contact with the pulleys.

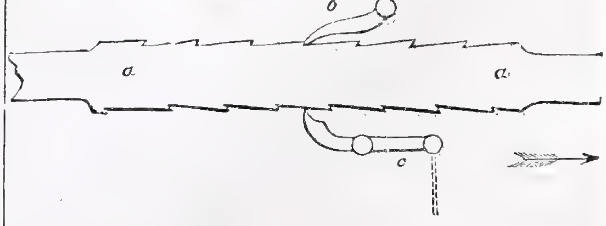
Fig. 7.



The box, *g g*, is made to pass along the shaft, *d d*, by peculiar mechanism hereafter to be noticed. The result of this is, that the belt, *h*, is made to pass from the small to the large end of the cone pulley, *h h*, and as the diameter of the pulley on the box, *g g*, is constant, the speed of the cone pulley and of its shaft, *m m*, is gradually reduced. As the rate of revolution of the cone pulley, *h h*, regulates the speed of the bobbins and the traverse of the copping rail, each movement of the box, *g*, and pulley, *f*, along the shaft, *d d*, is in exact accordance with the placing of each layer of cotton on the surface of the bobbin. How this is effected we have now to explain.

To the box or frame, *g g*, fig. 7, a chain is attached, shown by the dotted lines, *s s*, and carrying a counterbalance weight at its extremity. The tendency of this is to pull the box along the shaft, *d d*, unless prevented. To the box, a rack, *a a*, fig. 8, is attached. The teeth of this rack, on the edges, are placed alternately, the end of one being opposite the centre of the tooth below or above it. Being a part of the box, *g g*, the weight

Fig. 8.

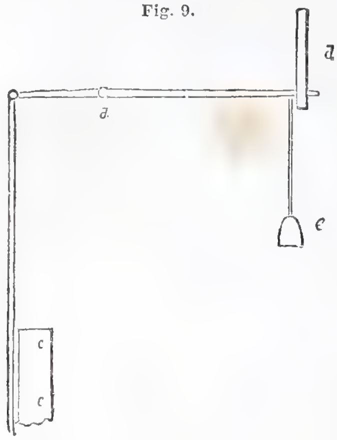


will have a tendency to pull the rack along also. To prevent this being done, except at the proper intervals, two clicks or pauls are used. One of these is always at the middle of a

tooth, while the other is at the end. If, then, one of these can be alternately disengaged, it is obvious that the weight will pull the rack along a distance on the shaft, *d d*, fig. 7, equal to half the length of a tooth of the rack. Each disengagement of a click or paul, as *b c*, fig. 8, will thus cause the belt, *h*, fig. 7, to pass up the surface of the cone, *h h*, fig. 7, a distance equal to the space of half a tooth on the rack, *a a*, fig. 8.

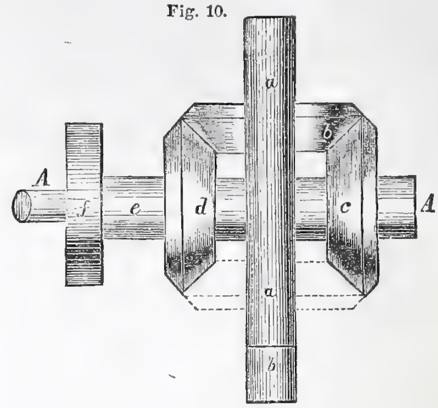
This alternate engagement and disengagement of the clicks, *b*, *c*, is the next mechanical movement to be described. Immediately behind the rack, *a a*, fig. 8, a vertical slide, *d*, fig. 9, is fixed. In this there is a slot, in which the end of a lever oscillating on the centre, *d*, is passed. The bar or vertical slide, *d*, has two projecting arms. The other end of the lever, oscillating on the centre, *d*, is provided with a vertical rod, which is connected with a rack, *c c*, forming part of the rack, *c c*, in fig. 6, which, as before explained, produces the traverse of the copping rail. A projecting arm is provided to the rack, *c c*, fig. 9. The vertical rod which is connected with the horizontal lever, *d*, fig. 9, has two catches or projecting arms, which can be adjusted at any part of its length. The two projecting arms on the vertical slide, *d*, fig. 9, act upon the clicks, *b*, *c*, of the rack, *a a*, fig. 8, one acting upon *b*, the other upon *c*. These arrangements being noticed, it will be seen how the rising of the rack, *c c*, fig. 9, will cause its projecting arm to strike one of the catches in the vertical rod, and raising thus one end of the horizontal lever, *d*, will depress the other, and pull down the vertical slide, *d*. The catch upon this will release one of the pauls of the rack, *a a*, fig. 8, and allow the weight to pull it along with the box, *g g*, fig. 7, a certain distance over the shaft, *d d*; by the descent of the rack, *c c*, the projecting arm will strike the other catch upon the vertical rod, bringing it down, depressing the end of the horizontal lever, *d*, raising the other, and the vertical slide, *d*; causing one of the catches to strike the paul of the rack, *a a*, fig. 8, and again allowing the weight to drag the box and rack along the shaft, *d d*, fig. 7. A weight, *e*, attached to the end of the lever, *d*, fig. 9, regulates the movements. The mangle wheel shaft, *a*, fig. 6, is driven from the shaft, *m m*, of the cone pulley, fig. 7. Thus an intimate connection is established between all the movements we have described, making them all self-adjusting and dependent one upon another.

Fig. 9.



The retardation of the speed of the bobbin by means of the cone pulley, although perfect for the manufacture of yarn with an invariable amount of twist in it, is not, however, in proportion when the twist is to be altered. Thus, to alter the twist the speed of the spindles is to be increased; but the rate of revolution of the bobbins must not be increased in the same proportion; that is, suppose the spindles to be driven with twice the speed, the bobbins must not be driven twice as fast as before, but must be such as to maintain the same ratio of difference between their speed and that of the flyers as before, while the rate of velocity of spindles and flyers may be increased as fast as necessary: in order to give any amount of twist, the relative difference between their speed and that of the bobbins must always be uniform. The necessary adjustment of the speed of the bobbins to that of the spindles is effected by the use of the beautiful equational movement of Mr. Houldsworth, known as the "differential movement." Let A A, fig. 10, be the main driving shaft. A toothed wheel, *a a*, revolves on this loosely, that is, the hollow boss on which the wheel, *a a*, is fixed, may have a motion independent of the main shaft, *a a*; or the wheel, *a a*, may be made to stand still while the shaft, *a a*, continues to revolve. The boss of *a a* is continued, and on it is fixed a bevil wheel, *d*, and a spur wheel, *f*. The bevil wheel, *c*, facing *d*, is fixed upon the shaft, *a a*, and partakes of its motion. A third bevil wheel, *b*, is made to revolve parallel

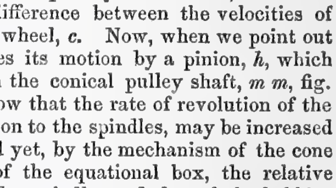
Fig. 10.



to the main shaft, its axis being at right angles to this. By moving the main shaft, *a a*, the bevil wheel, *c*, will transmit motion to the wheel, *d*, by means of the intermediate wheel, *b*; and as these bevil wheels are all of the same size, the motion of *d* will be equal to that of *c*, although in a *contrary direction.* By driving the wheel, *a*, at the same speed and in the same direction as *c*, the effect will be, that no motion will be communicated to *d*, and through that to the wheel, *f*, which is that which drives the bobbins. Thus, while the wheel, *aa*, is made to cease revolving, and the wheel, *c*, moves, the motion of *f*, and in consequence that of the bobbins, will be equal to that of the main driving shaft or wheel, *c*; but by driving the wheel, *a a*, at the same speed and in the same direction as *c*, the motion of the wheel, *f*, will be done away with, as also that of the bobbins. But by driving the wheel, *a a*, at a *slower* speed than *c c*, the wheel, *f*, and consequently the bobbins, will have their motion equal to the difference between the velocities of the wheel, *a*, and the bevil wheel, *c*. Now, when we point out that the wheel, *a a*, receives its motion by a pinion, *h*, which again receives motion from the conical pulley shaft, *m m*, fig. 7, it will at once be seen how that the rate of revolution of the shaft, *a a*, which gives motion to the spindles, may be increased to any required degree, and yet, by the mechanism of the cone pulley acting upon that of the equational box, the relative difference of the speed of the spindles and that of the bobbins is maintained invariably at the same ratio.

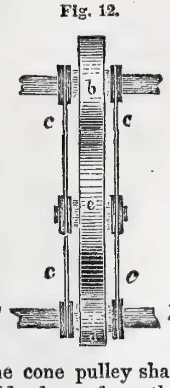
The horizontal shaft, having its bearing on the copping rail, which drives the bobbins, receives motion from the wheel, *f*, fig. 10; but as the copping rail moves up and down, it is evident that the wheel driving the horizontal shaft would be taken frequently out of gear with the wheel, *f*, fig. 10, which always remains at the same level, were not some means taken to obviate this. The following illustration will explain this means. The shaft of the wheel, *b*, fig. 11, derives its motion from a wheel driven by *f*, fig. 10. The wheel, *b*, fig. 11, gears into another, *e e*, the centre of motion being the point at which the two arms, *c*, *c*, join. These arms have their centre of motion on the shaft of wheel *b*, and on that of wheel *d*, which latter is the bobbin driving shaft. An edge view is given in fig. 12. *h h* is the bobbin driving shaft; *d* the wheel corresponding to *d* in fig. 11. As the copping rail ascends and descends, the arms, *c c*, move round their respective centres, thus linking the wheels together, and by means of the intermediate wheel, *e e*, keeping the wheel, *b*, driven by one, *f*, always in gear with *d*, which moves up and down with the copping rail. The box, *g g*, fig. 7, and rack, *a a*, fig. 8, on arriving at the end

Fig. 11.



of the slide in the shaft, *d d*, fig. 7, strikes a small projecting pin. This causes a lever to pass the main driving belt from the fast to the loose pulley, thus stopping the whole machine, and giving a determinate and equal quantity to all the bobbins. In order to prevent the sliver of cotton always passing over the same surface of the drawing rollers, it is placed between two rollers, having their bearings in a horizontal bar, which has a traverse motion from side to side equal to the length of the front drawing rollers. By this means the sliver is passed from end to end of these, and all indentation prevented, which would otherwise result were the sliver always passing over the same part of the surface. On the bobbins being filled, the attendant "or tenter" lifts the outer extremity of the cone pulley shaft, *m m*, fig. 7, thus allowing the belt to slide down from the large to the small end. The box, *g g*, fig. 7, is pulled back to its position opposite the small end of the cone, by means of a small winch, on which the chain is wound.

Fig. 12.



In frames where presser bobbins are used, the traverse of the copping rail has to be differently arranged, so as to give the conical form of the ends, as seen in fig. 2. The following is the mechanism by which the unequal traverse desiderated is carried out by Mr. Houldsworth. The arrangements of the rack, sliding pulley, and cone, are nearly the same as in the form of machine last described. To the under side of rack, *a*, fig. 13, a vertical arm, *b*, is attached. This has a slot in which a pin can move up and down, and be adjusted at any desired point. This pin forms the centre of motion of a lever, *d d*. A rod, *f*, shown by the dotted line, connects the upper extremity of this lever with the pulley, *f*, in the box, *g g*, fig. 8. To the under side of the copping rail, a vertical arm, with a horizontal slotted arm, *a*, is attached (fig. 14). In the horizontal slot, a bolt works adjustable at any point. This bolt or stud passes at the same time through a slot in the curved extremity of a lever, *b*. This lever has a double motion, one like the piston rod of a steam engine in the hollow boss or box, *c*, and also an oscillating motion round *c* as a

Fig. 13.

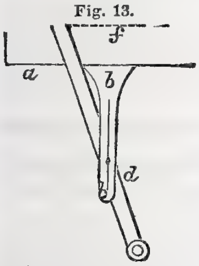
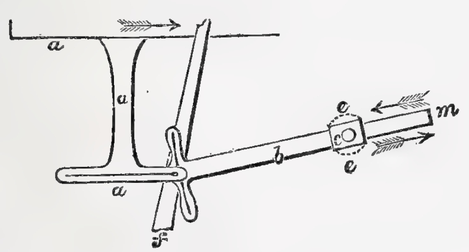


Fig. 14.

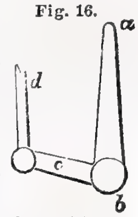


centre, the boss, *c*, being moveable on its centre. The end of the boss, *b*, therefore, describes an arc of a circle, the centre of which is at *c*. A lever, *f*, corresponding to *d d*, fig. 13, is attached to the curved arm of *b*, fig. 14, by a stud. If the lever, *d*, fig. 13, is made to slide in the slot of the arm, *b b*, it acts upon the lever, *b b*, fig. 14, so as to make it slide in and out in the boss, *c*, towards *m*, as shown by the arrows. Attached to the centre of the boss, *c*, fig. 14, is a tumbling lever, *a*, fig. 15. This is provided with a weight at the upper extremity, and having a curved slotted arm, *b*, and two catches or projecting pins, as shown. The lower extremity is notched. In the notch of the under part of the lever, *a*, fig. 15, the end *a*, of the bell crank lever, fig. 16, is passed. The consequence of this is, that as the lever, *a* fig. 15, moves from side to side, it actuates, in like manner, the bell crank, fig. 16, making the arm, *c*, move up and down as well as the lever with which it is provided. This rod engages and disengages the clicks or pauls *b*, *c*, of the rack, *a a*, fig. 8.

Fig. 15.

On the copping rail, *a*, fig. 14, rising, the lever, *b*, presses against the upper pin in the curved slot of *b*, fig. 15. This throws the lever, *a*, fig. 15, into such a position, that the weight at its extremity passes the centre of gravity, and it falls over; the reverse movement being effected by the descent of the copping rail, *a*, causing the lever, *b*, fig. 14, to press on the lower pin of the curved slot, *b*, fig. 15. The movement of the lever, *a*, fig. 15, causes also that of the bell crank, *a c*, fig. 16, and, by moving the rod, *d*, disengages one of the clicks of the rack, *a*, fig. 13, or *a a*, fig. 8. This, in its turn, moves the lever, *d*, fig. 13, or *f*, fig. 14, and consequently pushes the lever, *b*, fig. 14, outwards towards *m m*, through its boss, *c*. By thus acting upon the lever, *b*, fig. 14, it is evident that the length of the arm from *c* to the curved slot at its extremity is made less and less each stroke, *i. e.*, each ascent and descent of the copping rail. The extent, therefore, of the curve described by the extremity of the lever, *b*, fig. 14, will also become less and less. The pins, therefore, of the curved arm, *b*, fig. 15, will be more frequently struck. The bell crank motions, in like manner (fig. 16), will be more frequent also. By the movements of the lever, fig. 15, the traverse of the copping rail is regulated. Thus the vertical ascent of this and the bobbins thereon will also become less and less, giving the ends of the bobbins the conical form shown in fig. 2.

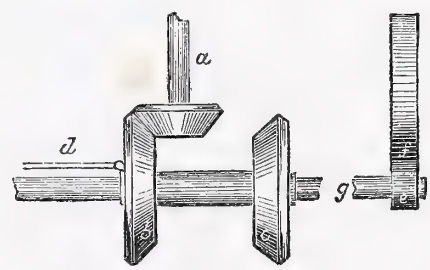
Fig. 16.



The traverse of the copping rail, as above noted, is caused by the movements of the tumbling lever, *a b*, fig. 15. Its connection with the copping rail will now be shown.

The wheel, *f*, fig. 17, gives motion to the pinion which works in the rack of the copping rail, fig. 6, the wheel, *f*

Fig. 17.



being moved by means of a small pinion, *e*, in the end of a horizontal shaft, *g g*. This shaft is thrown in and out of gear by the rod, *d*, which is connected with the tumbling lever, *a b*, fig. 15. The quicker the changes, the more frequent the ascent and descent of the copping rail, and also the extent of its traverse. The metre wheel, *a*, fig. 17, and shaft are driven by gearing by the cone pulley shaft, *m m*, fig. 7. The two wheels, *b* and *c*, are fixed in a boss, which is capable of moving along the shaft, *g g*, on a feather or rib, and yet partakes of the motion of *g*. By alternately throwing *b* and *c* into gear with *a*, the direction of motion of the shaft, *g*, pinion, *e*, and wheel, *f*, is alternately changed. This is effected by causing the lever, *d*, to be alternately pulled out and in by means of the tumbling lever, *a b*, fig. 15. Parallel to the tumbling lever, *a b*, fig. 15, a plate slides backwards and forwards. To the extremity of this, the rod, *d*, is attached. On the face of the plate a double catch is fixed. To the tumbling lever a projecting pin is provided, which is placed between the ends of this double catch; as the pin moves from side to side, by the tumbling of the lever, it catches each end of the catch alternately, and moving the plate from side to side, moves the lever, *d*, fig. 17, and thereon the wheels, *b*, *c*, alternately into gear with the wheel, *a*.

COMPENDIUM OF LOGIC.

CHAPTER IX.

PART V.—ON THE DISCOVERY OF TRUTH.—TRAINS OF REASONING.—INDUCTION AND DEDUCTION.—PERFECT AND IMPERFECT INDUCTIONS.

HAVING now examined the elements of reasoning, as these are developed in the syllogism—having shown what constitutes a sound, and what a fallacious argument, it still remains (to complete our Compendium of Logic) that something should be said of the manner in which the reasoner proceeds to the discovery or elucidation of truth.

ON THE DISCOVERY OF TRUTH.

All truth is not discovered by reasoning. Some facts are obvious to the senses by observation; some are perceived by the consciousness of what is passing within us; some are ascertained by experiment; some are received upon testimony. These four sources, therefore,—consciousness, observation, experiment, and testimony,—furnish to the mind the facts or premisses on which we reason. These are the four *direct* sources of knowledge; the fifth, and *indirect* source, is reasoning.

Now, it is, strictly speaking, to the process of reasoning alone that the principles of logic apply; and therefore it may appear, at first sight, that the science extends to only a limited portion of the vast field of human knowledge. Natural history, for example, is chiefly the fruit of observation. It consists of a record of the nature, structure, and peculiarities of animals, plants, &c. Civil history is based upon testimony. Chemistry is chiefly an experimental science. The facts of mental philosophy are drawn from consciousness. Mechanics, astronomy, optics, and the other mixed mathematical sciences, are partly the result of observation, partly of reasoning. The pure mathematics alone, including arithmetic and algebra, starting from a few elementary data (the intuitive character of which is disputed), consist entirely of reasoning.

In every science, however, the reasoning faculty is more or less called into operation. Science, properly so called, is knowledge classified. A mere confused accumulation of heterogeneous facts does not constitute science. Such facts could not be retained in the memory, or turned to any good account, without what is termed method—the result of classification; and this can only be accomplished by an exercise of the reasoning power, assigning to each individual subject its appropriate place in the system. From the premisses of certain observed properties, certain relations are *inferred*, and these again constitute the premisses from which to infer (or *argue*) a certain appropriate order of classification or arrangement.

Reasoning, moreover, teaches what to *reflect upon* in our own minds, what to *observe* with our senses, what *experiments* to make with a view to the discovery or verification of a truth, and what kind of *testimony* to receive as most likely to be true; so that, even in those sciences which draw their materials chiefly from other sources, the *reasoning power* is required to be in constant exercise. It operates as the guiding and governing power; first, in ascertaining facts; second, in arranging them properly; and, third, in communicating and applying them.

Reasoning is, therefore, coextensive with the whole field of human knowledge, though in some of the sciences it occupies a larger space, or appears in a much more condensed form than in others. Thus, as Whately remarks, "there are probably as many steps of pure reasoning in one of the longer of Euclid's demonstrations, as in the whole of an argumentative treatise on some other subject, occupying perhaps a considerable volume."

TRAINS OF REASONING.

Now let us see what constitutes a train of reasoning. "All men are mortal; Napoleon is a man, therefore, Napoleon is mortal," is *reasoning*, but not a *train of reasoning*. It constitutes a simple argument, expressed in the developed form of a syllogism. Still, if the premisses be granted, nothing more is required to prove that Napoleon is mortal. But let us suppose that the major premiss is called in question; then to establish our conclusion, we have another thing to prove, namely, that "all men are mortal." This must be performed by another syllogism, the premisses of which may be derived either from revelation or experience. If from revelation, we argue thus:—"What the scriptures say is true; the scriptures tell us that all men are mortal; therefore, it is true that all men are mortal." If from experience, the argument would take this form:—"Adam, Alexander, Cæsar, John, Thomas, and all other men in times past have died; but experience proves that the laws of nature are uniform; therefore, the highest probability exists that all men are mortal." This is really the utmost extent of the argument derived from experience. We cannot, in such a case, go further than to assert a very high probability that all men are mortal; and hence we can only infer an equally high probability, not a positive mathematical certainty, that Napoleon is mortal. For all practical purposes, indeed, the degree of probability is such as to amount to certainty. We think of it as certain,—speak of it as certain,—calculate upon it as certain; still there is only a moral, not a mathematical certainty; and even the scriptural argument may be subjected to the same limitation, by instancing certain exceptional cases recorded in the Bible itself.

Whether derived from experience or from scripture, this example of a train of reasoning consists of only two syllogisms. Generally, however, our reasoning is more complex, in illustration of which we may borrow the following example from Mr. Stewart Mill:—

> No government which earnestly seeks the good of its subjects is liable to revolution;
> The Prussian government earnestly seeks the good of its subjects;
> Therefore, it is not in danger of revolution.

"The major premiss in this argument," says Mr. Mill, "we shall suppose not to be derived from considerations *a priori*, but to be a generalization from history, which, whether correct or erroneous, must have been founded upon observation of governments, concerning whose desire of the good of their subjects there was no doubt. It has been found, or thought to be found, that these were not liable to revolution, and it has been deemed that those instances warranted an extension of the same predicate to any and every government which resembles them in the attribute of desiring the good of its subjects. But *does* the Prussian government thus resemble them? This may be debated *pro* and *con* by many arguments, and must, in any case, be proved by another induction; for we cannot directly observe the sentiments and desires of the persons who conduct the government of that country. To prove the minor, therefore, we require an argument in this form:—

> Every government which acts in a certain manner desires the good of its subjects;
> The Prussian government acts in that particular manner;
> Therefore it desires the good of its subjects,

But, is it true that the Prussian government acts in the manner supposed? This manner also may require proof; still another induction, as thus:—

> What is asserted by many disinterested witnesses must be believed to be true;
> That the Prussian government acts in this manner is asserted by many disinterested witnesses;
> Therefore, it must be believed to be true.

The argument hence consists of three steps. Having the evidence of our senses that the case of the Prussian government resembles a number of former cases, in the circumstance of having something asserted respecting it by many disinterested witnesses, we infer—first, that, as in those former instances, so in this instance, the assertion is true; secondly, what was asserted of the Prussian government being that it acts in a particular manner, and other governments or persons

having been observed to act in the same manner, the Prussian government is brought into known resemblance with those other governments or persons; and since they were known to desire the good of the people, we thereupon, by a second induction, infer that the Prussian government desires the good of the people. This brings that government into known resemblance with the other governments which were observed to escape revolution; and thence, by a third induction, we predict that the Prussian government will in like manner escape."

It will be observed, that, in these examples of trains of reasoning, we have supposed the reasoner to proceed *backward.* The first argument or syllogism gives the conclusion required; but one or other of the premisses from which that conclusion is drawn is supposed to be called in question, and this necessitates another argument to prove the disputed premisses of the first. Another argument supposes the assumption of new premisses. These, if not self-evident, must be again established in the same manner; that is to say, by another argument (or syllogism), having for its premisses facts that cannot be disputed; or, if they are still disputed, the reasoning must be carried backward by a similar syllogistic process, until we arrive at premisses resting either on acknowledged facts or incontrovertible principles.

This is one way of conducting a train of reasoning, and corresponds to *analysis.* It is the analytical method of reasoning. But having, by this retrocessory process, arrived at premisses so simple and obvious as not to admit of dispute, the reasoner may then retrace his steps, and starting from the elements thus admitted, rise or advance to his conclusion by a *synthetical* process. In this case, the conclusion of each argument becomes one of the premisses of that which follows. This is the progressive method of reasoning. It is that followed by Euclid, and followed in teaching or expounding systematically every science or system of truth.

INDUCTION AND DEDUCTION.

The proper and legitimate object of all science and reasoning is the discovery of truth. This involves two processes—first, reasoning from particular cases to general principles; and, secondly, reasoning from general principles to particular cases. Thus, from the fact that the ox, the elk, and all the other horned animals with which we are acquainted ruminate, we infer, as a general principle, that all horned animals ruminate. This is called reasoning from *Induction.* Again, from the general principle that all horned animals ruminate, we are prepared to infer, if we meet with some horned animal not hitherto observed, that this animal ruminates. This is reasoning by *Deduction.*

Induction (from *induco*, to lead or bring in) is the process of *bringing in* one fact after another, to establish a general principle or law of nature. Deduction (from *deduco*, to lead down) signifies the act or process of descending from generals to particulars—of reasoning from the general principles which have been established by induction to special conclusions.

The words are not always used in their strictly literal acceptation. *Deduction* is frequently applied to any process of inferring one fact from another, or even in the general sense of *conclusion; induction* is sometimes employed to signify the process of observing and collecting facts, sometimes the process of reasoning from these facts to general principles.

A certain latitude of application is often convenient in the use of words, and cannot always be avoided. In strictly philosophical language, however, terms should be clearly defined, and limited, if possible, to one meaning. In such language, properly used, the terms induction and deduction stand in some degree opposed to one another, but not completely. Induction is the process of investigating and collecting facts, from which we reason to general principles; so that we reason *from* induction, not *by* induction. Deduction, again, is the actual process of reasoning from these generals to particulars; so that we reason *by* deduction, not *from* deduction.

Thus, by a process of induction, we find or *observe* that Socrates, Cæsar, Alexander, John, Thomas, and all other persons who formerly lived have died: hence we reason as follows:—

Socrates, Cæsar, and all other men have died;
But what is true of these is probably true of all men;
Therefore, it is probable that all men are mortal.

This is an instance of reasoning *from* induction. But the probability attached to the conclusion is, in this case, so great that it is assumed as certain. Hence, we go a step higher, and lay it down as a general principle, that "all men are mortal." This proposition, accordingly, may now be made the major premiss of a *deductive* argument, as follows:—

All men are mortal;
Napoleon is a man;
Therefore, Napoleon is mortal;

—a conclusion drawn by deduction from a general principle, to which we were led by induction.

These very simple examples of the two processes in question, afford a complete epitome of what may be termed *the system of reasoning* in all the sciences. The first and fundamental process is induction—the investigation and collection of facts, either from consciousness, testimony, observation, or experiment. Reasoning *from* this induction of facts, we rise to general principles—principles which, when generalized to the utmost, we term laws of nature; and these being fully established, we then commence the deductive process, and apply them to the explanation of particular cases.

Thus, it is found by a wide experimental induction, that sulphuric acid, hydrochloric acid, and all the other acids with which we are acquainted, have the property of turning vegetable blues red. Hence it is inferred, as a general law, that acids redden vegetable blues. This is an inference *from* induction, not the induction itself. Then commences the deductive process. Some substance is brought to a chemist, of whose nature he is ignorant; he finds that it reddens vegetable blues, and thence infers from the general principle that this substance is an acid.

The inductive process is, therefore, the basis of science. It forms the solid foundation on which the superstructure is erected; and the wider the induction, the higher and more secure will be the superstructure. Hence the vast importance of induction, and hence the enormous impetus which Lord Bacon gave to science by teaching the absolute necessity of climbing by a patient induction to the knowledge of general truths. Previously, the world had chiefly trusted to the reasoning or imaginative powers of the mind to elucidate the mysteries of nature. Ideas took the place of facts, and logic was the great alembic in which unsubstantial theories were sublimed into airy philosophical systems. The consequence was, that, except in the science of pure mathematics, which rests upon a few elementary axioms, and does not require the preliminary drudgery of a patient induction of facts, very little progress had been made till the time of the illustrious Bacon. His *Novum Organon* (or New Organon), so called—as formerly stated—in contradistinction to that of Aristotle, laid the foundation of a new system, which speedily effected a complete revolution in science. Previously, system had succeeded system—one philosophical theory had quickly superseded another—all were alike unstable and evanescent, for all were alike deficient in the one indispensable requisite of resting on a solid basis of facts. The father of the inductive philosophy proclaimed with a clear and distinct voice, the great fundamental error which had led men so long astray, and kept the philosophical world so long in comparative darkness—the error of attempting to *reason out* truth without accumulating positive data from which to reason correctly. He urged the necessity of interrogating nature by observation and experiment—of thus interrogating nature itself with a view to the discovery of nature's laws, instead of interrogating only the reasoning or imaginative powers of the human mind. His doctrine, so clearly expounded, so irresistibly enforced, was soon all but universally accepted and reduced to practice. The visions of theory and speculation were banished. The wordy and quibbling disputes of the school logomachists were silenced. A new era in philosophy dawned. Men began everywhere to exercise their senses—to seek truth by careful observation—to interrogate nature by experiment—to labour in the field and in the laboratory in quest

of facts—then to consider, compare, arrange, and classify, until, from this broad and careful induction, they have succeeded in eliciting with positive certainty many of the laws or principles which guide the operations of nature. The knowledge of these laws, thus acquired, is that which imparts a command over nature, for purposes useful to man. Hence the triumphs of astronomy, chemistry, and other physical sciences—the fruits of the Baconian or inductive system—which have taken the place of astrology, alchemy, and other superstitious absurdities of the middle ages.

We have said that induction is the basis of science. There is, however, a period in the progress of scientific discovery when the inductive method must yield the palm to deduction. Astronomy, for example, is now chiefly a deductive science. The grand principle of gravitation having been established by Newton from a wide induction—having been found to explain a vast variety of facts which had been previously regarded as unconnected—has led to a clear understanding of the laws which govern the motions of the planets, and the influence of the moon upon the earth. The work of the astronomer now chiefly consists in applying these laws to explain particular facts as they arise, or to predict particular combinations of the heavenly bodies. The discovery of the planet Neptune a few years ago, was probably the greatest *deductive* achievement recorded in the annals of science—the existence and actual position of the planet having been deduced from the established laws of astronomy, as bearing on certain observed disturbances, so precisely, that the planet was discovered in the very part of the heavens to which astronomical observers were directed to look for the mysterious stranger—the hitherto invisible troubler of our solar system. This was a sublime example of pure deduction; and similar triumphs will attend others of the physical sciences, as well as the social and mental sciences, when these become more advanced and complete. In Bacon's time, induction was the principal requirement, for no foundation had been laid on which to erect a superstructure; but now that, in several of the sciences, a vast mass of facts are accumulated, and many important general laws are evolved, we begin to approach the period when the further progress and extension of knowledge will be chiefly the result of deduction. "In the present state of knowledge," says Mr. Stuart Mill, "the deductive method is destined irrevocably to predominate in the course of scientific investigation from this time forward. A revolution is peaceably and progressively effecting itself in philosophy, the reverse of that to which Bacon has attached his name. That great man changed the method of the sciences from deductive to experimental, and it is now rapidly reverting from experimental to deductive. But the deductions which Bacon abolished were from premisses hastily snatched up, or arbitrarily assumed. The principles were neither established by legitimate canons of experimental inquiry, nor the results tested by that indispensable element of a rational deductive method, verification by specific experience. * * * That the advances henceforth to be expected, even in physical, and still more in mental and social science, will be chiefly the result of deduction, is evident from the general considerations already adduced. * * * * Deduction is the great scientific work of the present and of future ages. The portion henceforth reserved for specific experience in the achievements of science, is mainly that of suggesting hints to be followed up by the deductive inquirer, and of confirming or checking his conclusions."

PERFECT AND IMPERFECT INDUCTIONS.

It is commonly stated in logical works, that arguments derived from induction are not perfect, unless the induction has extended to every individual of the class of which the conclusion is predicated. Thus, if the fact has been ascertained that every individual or species of the class of horned animals ruminates, then the conclusion, that "all horned animals ruminate," is said to be a perfect inductive argument. If this definition be accepted, however, we must frankly acknowledge that in science there are few perfect inductions. Nay, we must farther admit that such inductions are comparatively useless; for if we have already ascertained the fact to be affirmed or denied of *every individual* of a class, the general principle thereby established cannot be of any importance in reasoning back to particulars. There remains, in short, nothing for deduction to do. The particular cases are exhausted—no new examples can arise to which we can apply the deductive argument with any advantage. The value of deduction proceeds from the very *imperfection* of induction, in the literal meaning of the word; from the fact, that in the great majority of cases we do not and cannot extend our induction to every individual of a class, but merely so far as to lead to the rational inference, that what we have observed of every individual that has come under our cognizance, may, with something approaching to certainty, be predicated of the whole class. Then we infer, by deduction, that the same may be affirmed or denied with reference to other individuals which have *not* come under our cognizance, or *not* been subjected to experiment or observation, further than to ascertain that they belong to the class in question.

But while we affirm that imperfect inductions are of much more frequent occurrence than perfect ones, and occupy a far more important place in the sciences, we beg to remind the reader that we do not use the word in the sense in which it is defined by Mr. Mill, namely, as "that operation of the mind by which we *infer* that what we know to be true in a particular case or cases, will be true in all cases which resemble the former in certain assignable respects." We do not use the word *induction* as meaning a process of inferring or reasoning at all, but simply to express the preliminary process of making particular observations, investigating certain facts, and bringing together the results of inquiries, *from* which to infer. This is a distinction of the greatest importance, and though it is true that Mr. Mill adopts, as his definition of the word, one of the senses in which it is frequently used, yet he appears to be led by that definition into some confusion of ideas with regard to the meaning of a true inductive inference. "Induction," he says, "as above defined, is a process of inference; it proceeds from the known to the unknown; and any operation involving no inference, any process in which what seems the conclusion is no wider than the premisses from which it is drawn, does not fall within the meaning of the term. Yet, in the common books of logic, we find this laid down as the most perfect, indeed the only quite perfect form of induction. In those books, every process which sets out from a less general and terminates in a more general expression—which admits of being stated in the form, 'This and that A are B, therefore every A is B,'—is called an induction, whether anything be really concluded or not, and the induction is asserted to be not perfect, unless every single individual of the class A is included in the antecedent, or premiss; that is, unless what we affirm of the class has been ascertained to be true of every individual in it, *so that the nominal conclusion is not really a conclusion, but a mere reassertion of the premisses.* If we were to say, All the planets shine by the sun's light, from observation of each separate planet; or, All the apostles were Jews, because this is true of Peter, Paul, John, and every other apostle—these, and such as these, would, in the phraseology in question, be called perfect, and the only perfect inductions. This, however, is a totally different kind of induction from ours; it is no inference from facts known to facts unknown, but a mere short-hand registration of facts known. The two *simulated* arguments which we have quoted, are not generalizations; the propositions purporting to be conclusions from them, are not really general propositions. A general proposition is one in which the predicate is affirmed or denied of an unlimited number of individuals; namely, all, whether few or many, existing, or capable of existing, which possess the properties *connoted* by the subject of the proposition, 'All men are mortal,' does not mean all now living, but all men past, present, and to come. * * * The operation [of what is called a perfect induction] may be very useful, as most forms of abridged notation are; but it is no part of the investigation of truth, though often bearing an important part in the preparation of the materials for that investigation."

We have given this somewhat lengthened extract, because it contains, as we conceive, a mixture of truth and error, by a due discrimination of which the reader may arrive at a just idea of induction, and its use in the investigation of truth. We cannot object to the employment of the word in that sense

in which Mr. Mill defines it, provided it be clearly understood to be used in that sense alone; although we believe it to be better to apply it in the literal sense, in accordance with our own definition, which is that of Archbishop Whately. There is no other word to express this meaning; and when it is applied in this sense, we can speak without ambiguity of reasoning or generalizing *from* induction.

But allowing that the word, if distinctly defined, may be legitimately used to express an inferring or reasoning process, and, further, admitting the correctness of Mr. Mill's definition of a *general proposition*, as a name that cannot, with propriety, be applied to the result of a perfect induction, still we assert that he is wrong in affirming that the "nominal conclusion" from such a perfect induction is "not really a conclusion, but a mere reassertion of the premisses"—a "simulated argument"—"no inference from facts known to facts unknown, but a mere short-hand registration of facts known." We hold that the conclusion drawn from a perfect induction is something more than this—we affirm it to be really an inference as much as any other argument—the only *universal* inference from induction which can be justly regarded as quite conclusive. Mr. Mill appears to have overlooked the fact, that one point which must be ascertained in order to draw what he terms a "nominal conclusion" from a perfect induction, is, that the several individuals enumerated constitute the *whole* of the class to which they belong. When this is ascertained—and not till then—the premisses will really involve the conclusion; but so do the premisses of every valid argument, for if they did *not* involve the conclusion it would not be an argument at all. Thus we may exhibit the inference drawn from a perfect induction in the shape of a faultless syllogism:—

Peter, Paul, John, &c. *(enumerating the rest of the apostles)* were Jews;
But these were all the apostles;
Therefore, all the apostles were Jews

This we hold to be a perfectly valid argument—an argument involving an inference as much as any other argument—and yet it is founded on a perfect induction; for it is assumed that in the major premiss the names of all the apostles are enumerated, as, "Peter was a Jew," John was a Jew," "Paul was a Jew," and so on. But then, to enable us to draw the conclusion, that "all the apostles were Jews," we require the assertion in the minor premiss that these individuals, so enumerated, constituted *all* the apostles. This completeness of the list may, in thousands of similar cases, be perfectly manifest; but it may sometimes be otherwise, as even, for instance, in the other example given by Mr. Mill himself; for, when we enumerate successively the names of all the known planets, asserting, "from observation," that each of them shines by the sun's light, it does not follow that "all the planets do so," unless we can affirm (what is very doubtful) that these are *all* the planets. We know that a list of the planets by name would have been very incomplete a few years ago.

The process of reasoning, or, if we may call it so, generalizing, from a perfect induction, is therefore a process which involves a strictly logical inference. It is, moreover, as already stated, the only form of inductive reasoning which yields a universal conclusion possessing the force of demonstration, and this for the very reason, indeed, that the induction is complete or perfect, and therefore the conclusion no wider than the premisses. Any conclusion which is wider than the premisses, that is to say, which is founded upon an imperfect induction, must of necessity be liable to some uncertainty, and that uncertainty is measured exactly by the extent of the induction. Thus, from the induction that "Cæsar, Alexander, John, Thomas, and every other person who has formerly lived, has died," we cannot, by a process strictly logical, draw the universal conclusion that "all men are mortal," unless we can assert as a minor premiss, that what has happened to these men will certainly happen to all men, which, however, would involve a begging of the question. The induction in this case is wide enough to give to the conclusion a high degree of probability; but not less extensive *in proportion* was that induction from which it was inferred, before the discovery of Australia, that all swans were white. This was universally believed by the ancients; so much so, that the phrase "a black swan" was used as an equivalent expression for something absurd or incredible. This was founded on the *almost perfect induction* that a black swan had never been seen or heard of; and yet that the induction was imperfect, and that such an imperfect induction, even though sufficiently extensive to lead to universal conviction, is far from equivalent to demonstration, and may, in fact, constitute the ground of an absolutely false conclusion, is proved by the result in this case.

But how does it happen, that although the induction of particular cases, from which we infer that all men are mortal, is not more extensive than that from which it was formerly inferred that all swans were white—how does it happen, we ask, that the acknowledged failure of the truth of the latter does not shake our conviction of the truth of the former proposition? We have said that *the extent of an induction is always the measure of the certainty of the generalization inferred from it.* We do not hesitate to say so with reference to the two cases before us. The argument derived from the simple induction we have mentioned, goes not a step farther in the one case than it must have done in the other before black swans were discovered. The conclusion that all men are mortal, *so far as derived from the mere induction of particular cases of mortality*, was not more certain to our ancestors than the erroneous conclusion derived from a similar induction, that all swans were white. And yet we feel a positive assurance, amounting to absolute conviction, that in no part of the world, even supposing that regions exist which are yet unexplored, will any race of men be discovered that are not mortal. Does not this seem to indicate that some inductions, though not more extensive than certain others, may lead to a stronger assurance, amounting to positive certainty? We answer that, in cases where the inductions are equally extensive, the force of the arguments derived from the inductions is equal also; but the conclusion in the one case may fail to command our conviction, having nothing but the mere induction to rest upon, while in the other it may be confirmed by auxiliary arguments which give it the force of demonstration. Thus, from the mere induction that all men who formerly lived have died, we do not and cannot conclude, with certainty, that all men will die hereafter; we have, indeed, a positive conviction that all men are mortal, but this conviction is derived from the fact, that the argument afforded by a wide induction is equally supported by reason and by revelation. From the seeds of disease and mortality in the human frame—from the general analogy of nature in the animal and vegetable world, in which we observe that every organized being is liable to decay and dissolution—from the fact that, if successive generations did not die, the earth would speedily be overpeopled—from these and similar arguments, combining with the positive assurance of revelation that "all men shall surely die," we feel that the conviction of human mortality, both as regards the present and the future, rests upon a basis of evidence virtually equivalent to demonstration. On the other hand, the general proposition that all swans were white, rested on a single imperfect induction—an induction as extensive, indeed, as that which had favoured the conclusion that all men are mortal, but not confirmed like the latter by a number of powerful concurrent arguments. In the first place, it was not confirmed by analogy, for even animals in a wild state exhibit occasional variations in colour; and nothing can be more diversified than that of domesticated animals. Here, therefore, was another induction which stood in a kind of opposition to the first, and rendering it not improbable, at least, that swans of a different colour might exist. Again, it was not confirmed by the argument *a priori*, that any peculiar fitness or necessity existed for swans being white, in preference to black or grey, or any other colour. There was no authoritative statement on the subject—nothing but the evidence or argument of one *imperfect* induction, from which it appeared that all the swans that had ever been seen or heard of were white. The conclusion, therefore, that all swans are white, did not, even when the fact was believed in the absence of contrary evidence, rest upon the same amount of proof or presumption as that which produces the conviction that all men are mortal. So far as appertains to the single induction in each

case, the evidence in favour of each of the conclusions was equal; but the former was supported by the single induction alone, the latter is supported by other inductions and other arguments, which, when combined with the first induction, render the conclusion as nearly as possible a matter of demonstration; we do not say of absolute demonstration, for, as in the case of the imperfect induction from which we infer that all men are born of woman, we must except the first man, who could not have been born of woman, so, in the case of the imperfect induction from which we infer that all men are mortal, those who believe in the truth of revelation must admit an exception as regards the *last men*—those who are to live upon the earth at the time of its ultimate destruction.

We have dwelt at considerable length upon this point, because it illustrates the principles on which we are to estimate the force of an argument derived from induction. A perfect induction cannot deceive: it yields a conclusion so obvious and certain that Mr. Mill has erroneously declared it to be no conclusion or inference at all, but "a mere reassertion of the premisses." Imperfect inductions, on the contrary, even though so wide as to embrace an almost indefinite number of cases, may, and frequently do deceive, and therefore cannot be trusted, unless they are supported by other inductions or other arguments. This, therefore, constitutes the test of a good induction; and such is its force that a single case will sometimes be sufficient to establish a general law in a manner that does not admit of doubt, while, as we have seen, an unlimited number of cases, when otherwise unsupported in their evidence, may absolutely fail to do so, or even may lead the inquirer to a false conclusion. "Why is a single instance," says Mr. Mill, "in some cases sufficient for a complete induction, while in others, myriads of concurring instances, without a single exception known or presumed, go such a very little way towards establishing a universal proposition? Whoever can answer this question knows more of the philosophy of logic than the wisest of the ancients, and has solved the great problem of induction." We hope we have enabled the reader to solve this important problem. A single case will be sufficient, when we are aware, from other inductions, that a single case of that description must indicate a general law. Thus, when Benjamin Franklin drew electricity from a thunder-cloud, the fact that such clouds are charged with electricity became immediately established and credited, because it was known, from a previous induction, that Franklin was a man entitled to be credited, and also that thunder-clouds exhibit the same peculiar phenomena in every part of the world. But when we find that the weather has been fair for a great many days in succession, we do not infer from this induction that it will not rain on the next, because we are assured, by a still more extensive induction, that the weather is liable to change in a few hours.

A perfect induction is, therefore, the only induction from which we are enabled to draw a universal conclusion with positive certainty, although, when we have other inductions or other arguments to help us, we may arrive at an almost certain conclusion from a very imperfect induction. In this case, however, the imperfect induction is an argument resting upon other arguments; and still there will remain a degree of uncertainty unless a conclusive demonstration be supplied by the other arguments alone, in which case the truth of the conclusion does not rest on the induction, but is merely corroborated thereby.

On the whole, it will be seen that an imperfect induction affords, when considered separately, or as unsupported by other arguments, merely a *presumptive inference* of the truth of any general law. Now, as the induction must be incomplete or imperfect in every case in which the conclusion is wider than the premisses, and this being the only kind of induction which Mr. Mill admits to be "part of the investigation of truth," it follows that, in every such case of induction, the inference is merely presumptive; and this we conceive to be the meaning which Mr. Mill unconsciously attaches to the word, when he says that in a perfect induction there is no inference. The truth is, that a perfect induction leads to an infallible inference. The conclusion is so obvious and certain, that it seems to involve no exercise of reasoning, whereas it is arrived at by a process of strict demonstration. The word *inference*, as used by Mr. Mill, evidently means a process in which there is room for conjecture, and therefore liability to error—room for the exercise of shrewdness and sagacity, and therefore, as must necessarily happen, not a mathematical certainty, in which case *the whole of the conclusion* must always be involved in the premisses.

To some extent, however, Mr. Mill is right. The work of investigating truth, which constitutes the business of science, is chiefly conducted by imperfect inductions, or those in which general conclusions are *presumptively inferred* from limited premisses. Of course we speak of the inductive sciences. In those which are deductive, such as the pure mathematics, and in even the inductive sciences, so far as they partake of the deductive element, the inferences are not presumptive but positive. More or less presumptive they always must be, when, in Mr. Mill's own language, the conclusion is wider than the premisses.

And thus it is that all the ingenuity, all the dexterity and skill evinced in the inductive sciences are brought into play. The induction of a few cases gives a result in which an ingenious and reflecting mind perceives or infers the operation of a general law. From that induction alone, however, the truth or existence of the general law may be doubted. Other cases are investigated, other inductions are applied as a test of the credit which is due to the inference from the first induction; and thus the inquiry branches out into a number of different investigations, all of them more or less bearing on the question, and probably concurring in the ultimate result to establish, with something like the force of demonstration, the existence of a general law which had only been *presumptively inferred* from the first induction. It is, however, this presumptive inference which Mr. Mill seems to consider as equivalent to a logical inference, when he uses language which implies the assertion that no inference can be drawn from a perfect induction. It is true that the word *inference*, when used without any qualifying adjective, is frequently employed to signify the drawing of a doubtful conclusion. We *infer* that the weather will be fair when the barometer rises—we *infer* that it freezes when we observe that the thermometer is under 32°. In the former case, however, we merely conjecture—we consider the result predicted to be more probable than otherwise; while, in the other case, we do not conjecture but *conclude*—we know for certain that it freezes when the thermometer indicates less than 32°. The word *inference* is therefore ambiguous, or rather it signifies merely the drawing of some conclusion, whether that conclusion rests upon doubtful or positive evidence. Mr. Mill seems to be misled by this ambiguity of the word when he asserts, that in the case of what is termed a perfect induction there is *no inference*, or, as he elsewhere expresses it, merely a *nominal* conclusion, which really means no conclusion.

The matter may be briefly summed up as follows:—The inference from a perfect induction is a strictly logical inference, possessing the force of demonstration; that from an imperfect induction, however numerous the cases examined, is merely presumptive in its own evidence, but may be rendered as nearly conclusive as possible by the corroborative evidence of other inductions and arguments. The first kind of inference is decisive, precluding the necessity for further investigation; hence it is chiefly by the second kind of inference that men are required to pursue the research after truth in the inductive sciences. So long as the induction is imperfect, ground for investigation remains; and this investigation or search after truth, is the very thing that constitutes science.

INORGANIC CHEMISTRY.

CHAPTER IX.

ALUMINIUM.

Alumina is best precipitated from the solution of its compounds by carbonate of ammonia, or pure ammonia, where the presence of carbonic acid would be hurtful. The precipitate must be very carefully washed with hot water. Some natural

compounds of alumina can only be dissolved by fusing the finely powdered and sifted mass with bisulphate of potash, in a platinum crucible. The residue is then soluble in water. In this case the alumina after precipitation must be redissolved in muriatic acid, and again thrown down by ammonia.

If phosphoric acid is present, it is precipitated by ammonia along with the alumina. A separation is thus effected. We dissolve the precipitate in caustic soda, dilute with water, and precipitate the phosphoric acid with chloride of barium. More soda is added, the liquid raised nearly to the boiling point, filtered, and the filtrate treated for alumina, as above. The precipitate of phosphate of baryta is dissolved in muriatic acid, the baryta precipitated with sulphuric acid, and afterwards the phosphoric acid with sulphate of magnesia and ammonia. This precipitate is formed very slowly.

To separate alumina from magnesia, the solution, unless highly acid, is mixed with chloride of ammonium, and the alumina then precipitated, as above. The precipitate is collected on a filter and slightly washed. The moist filter, with its contents, is then put in a glass, drenched with muriatic acid, avoiding excess, the liquid filtered, and the filter well washed. The hydrochloric solution is now treated with potash in excess, and the whole heated in a platinum capsule, filtered, and washed. The filter, with its contents, is digested in hydrochloric acid, well washed, and the solution thus obtained (magnesia) is added to that containing the larger proportion of this earth. To determine the alumina held in solution by the caustic potash, muriatic acid is added in slight excess, so as to redissolve the precipitate first formed. From this solution the alumina is thrown down by carbonate of ammonia.

To separate alumina from lime, the solution is supersaturated with pure ammonia (free from carbonate), which precipitates alumina alone. The precipitate is thrown on a filter as quickly as possible, and the funnel covered with a well-fitting glass plate. From the filtrate lime is precipitated as usual with oxalate of ammonia. The alumina is ignited and weighed, drenched with water and strong muriatic acid. If an effervescence ensue, carbonate of lime is still present. In this case the alumina is redissolved in the acid, and reprecipitated with ammonia, whilst the clear liquid containing the trace of lime is added to the first portion of lime.

When alumina, lime, and magnesia exist together, chloride of ammonium is added to the solution, and the alumina thrown down with pure ammonia, proceeding as above. After removing the lime from the clear liquid as oxalate, the magnesia is determined as usual.

The separation of alumina from strontia is effected precisely as in the case of lime.

Alumina and baryta are separated by means of sulphuric acid, which precipitates the latter.

From the fixed alkalies, alumina is separated by carbonate of ammonia. The filtrate is evaporated to dryness, and the residue ignited in a balanced crucible.

If magnesia, lime, and a fixed alkali be present along with alumina, a very frequent case in minerals, we proceed by adding chloride of ammonium and pure ammonia. Alumina falls, along with a little magnesia. We filter rapidly to prevent the formation of carbonate of lime, and throw down lime from the clear liquid as oxalate. The trace of magnesia precipitated along with the alumina is separated by a solution of potash, and dissolved in an acid, as above. This acid solution is added to the liquor filtered from the oxalate of lime, evaporated to dryness, ignited, treated with sulphuric acid, dried, and again ignited.

GLUCINIUM.

Glucina is precipitated as alumina. To separate these two earths, they are both thrown down by ammonia, washed, mixed with water, and a current of sulphurous acid gas transmitted until the whole is dissolved, when the liquid is boiled. Basic sulphate of alumina is precipitated, which is filtered off and washed. Glucina remains in solution, and may be precipitated by ammonia. From lime, strontia, baryta, and the alkalies, glucina is separated by the same means as ammonia.

THORIUM.

Thoria is precipitated from its solutions by pure ammonia; or, preferably, sulphate of potash is added, boiling or concentrated, to the solution of thoria, as long as it is rendered turbid. The precipitate is washed with a cold saturated solution of sulphate of potash, and dissolved in boiling water, from which thoria is thrown down by means of caustic potash. In this manner thoria may be separated from most other substances.

From alumina and glucina, thoria may be separated by caustic potash, in which the two former dissolve. From magnesia it is separated by means of ammonia from a muriatic solution. Thoria is thrown down, whilst magnesia remains dissolved. From lime it is also separated by ammonia, filtering rapidly. From the alkalies it is separated by the same reagent.

YTTRIUM.

Yttria is precipitated from its solutions by the fixed caustic alkalies. If the solution be a sulphate, the precipitate must be allowed to stand for some time before filtering; the precipitate is then ignited, dissolved in dilute nitric acid, and reprecipitated by potash. Yttria may be advantageously precipitated as oxalate by adding oxalic acid to a solution first acidulated with muriatic acid. The oxalate, on ignition, is converted into pure yttria. From alumina and glucina it is separated by heating the solution with potash, and prolonged digestion, when the two former are dissolved. From magnesia it is separated by ammonia, chloride of ammonium having been previously added. From the alkaline earths and alkalies it is separated as is alumina.

CERIUM.

The oxides of cerium are precipitated by caustic potash. After ignition, a peroxide is always obtained. From yttria, cerium is separated by mixing the concentrated solution with a concentrated boiling solution of bisulphate of potash. The precipitate is treated like that of thoria. From the earths and alkalies, ceric oxide is separated like yttria. The method of separating cerium from lanthanum and didymium is very imperfect.

ZIRCONIUM.

Zirconia is precipitated by caustic potash, and by sulphate of potash in crystals, keeping the liquid exactly neutral by the cautious addition of pure potash. The precipitate is washed with water containing a little ammonia, boiled with caustic potash, ignited and weighed as hydrate of zirconia. Zirconia may be separated from alumina, magnesia, lime, strontia, baryta and the alcalies, by pouring the solution drop by drop into bicarbonate of soda. The zirconia is entirely precipitated by boiling, adding chloride of ammonium, and boiling again. From ceric oxide, yttria, and glucina, it cannot as yet be accurately separated. According to Berzelius, the boiling solution is mixed with sulphate of potash, which throws down the zirconia. To the acid solution a little ammonia is added. The precipitate is slightly washed with pure water, and then treated with caustic potash.

MANGANESE.

Protoxide of manganese is precipitated by carbonate of soda. The liquid should be warmed after precipitation. The same precautions are requisite as in the case of magnesia, but the washing can be carried to a greater length. Ignition converts it into a mangano-manganic oxide, from whose weight that of the original protoxide is calculated. If an excess of alkali be carefully avoided, or if the bicarbonate of soda be employed, a permanent carbonate is obtained, which may be weighed as such. The sesquioxide of manganese may be precipitated by ammonia, but, as the subsequent ignition of the precipitate requires a very high temperature, it is preferable to convert the solution into a proto-salt, by long digestion with muriatic acid. It is then precipitated with carbonate of soda, as above. The commercial estimation of black oxide of manganese will appear in a subsequent chapter.

Separation of manganese from zirconia, ceric oxide, yttria, and thoria is thus effected:—The mixture is ignited, and afterwards treated with dilute nitric acid free from nitrous acid, which dissolves the earths, leaving manganese untouched.

From alumina and glucina, manganese is separated by boiling the solution with caustic potash in excess. From magnesia, manganese is separated by adding chloride of ammonium,

ammonia, and hydrosulpuret of ammonium. The precipitate must be allowed to stand for some time before it is filtered. On the filter it is washed with an exceedingly dilute solution of hydrosulphate, (3 drops to 1 oz. water). The whole is then treated with hydrochloric acid, dissolved, and heated as long as it smells of HS. It is then filtered, and the manganese precipitated as usual. The first filtrate contains all the magnesia. It is acidulated with hydrochloric acid, digested for a long time, filtered to remove suspended sulphur, and the magnesia determined as usual.

The separation of manganese from lime is precisely similar. Great care is needful to prevent exposure to the air.

If a trace of manganese has to be removed from a mixture containing alumina, magnesia, and lime, chloride of ammonium is added, and then ammonia, which precipitates alumina. During filtration the air is carefully excluded. From the filtrate, oxalate of ammonia throws down the lime. As the precip. of alumina contains a trace of manganese and magnesia, it is boiled in potash and filtered; the two latter bases remaining insoluble are dissolved in muriatic acid, and mixed with the filtrate from the lime. The manganese is then separated from the magnesia as above. If the amount of manganese is large, the alumina along with a trace of magnesia and manganese, is precipitated by ammonia; the liquor filtered, and the bulk of the manganese precipitated by hydrosulphate of ammonia. The clear liquid is acidulated with muriatic acid, digested to expel HS, filtered, neutralised with ammonia, and the lime thrown down as oxalate. The sulphuret of manganese is dissolved in muriatic acid. From this solution, oxide of manganese is precipitated by ammonia. The magnesia is precipitated from the liquor filtered from the oxalate of lime, and the traces of manganese and magnesia thrown down along with the alumina are separated and determined as above.

From strontia, manganese is separated by adding chloride of ammonium, ammonia, and hydrosulphate of ammonia. In filtering the sulphuret, care is required to exclude the air.

From baryta, manganese is separated by sulphuric acid.

If manganese occurs along with the alkalies, it is precipitated by hydrosulphate of ammonia.

IRON.

This metal is almost always determined as peroxide. If existing in any other state, the solution is peroxidized by heating with nitric acid. Peroxide of iron, where it exists alone, is precipitated by ammonia. In ignition, the heat should be applied cautiously at first. In many instances iron is precipitated as sulphuret, in order to separate it from other bodies. The liquid, if acid, is neutralised by ammonia, and then hydrosulphate of ammonia is added. The precipitate is rapidly filtered and washed with water containing a little hydrosulphate of ammonia. Whilst still moist it is then dissolved in muriatic acid, warmed to expel HS, filtered, the filter washed, nitric acid added, and heat applied. The iron in the solution thus peroxidized is precipitated by ammonia. Ores of iron may also be directly determined in the dry way. The ore is well powdered, and added to a mixture of cyanide of potassium and carbonate of potash. The whole is then strongly ignited in a porcelain crucible. The reduced iron may be obtained in a state of purity by washing with cold water.

To separate iron from manganese, acetate of soda is added, and a stream of chlorine gas is passed through the solution. Manganese is precipitated as peroxide, whilst iron remains in solution.

To separate iron from zirconia, the substances dissolved in muriatic acid are saturated with HS, and ammonia added in excess. The precipitate is allowed to stand, air being excluded, the supernatant liquid decanted off as far as possible, and an aqueous solution of sulphurous acid is added to the precipitate. This dissolves the iron as hyposulphite, whilst the zirconia remaining is filtered off, washed, and weighed. The filtrate is oxidized with nitric acid, and the iron precipitated with ammonia.

From cerium, iron is separated by means of the sulphate of potash, like yttria.

From yttria, iron is separated by saturating the mixed solutions with ammonia, and precipitating the iron by succinate of ammonia. From the filtrate the yttria is thrown down by excess of ammonia. The solution should be dilute, and the whole should be heated after precipitation of the iron by the succinate. From thoria, iron is separated by sulphate of potash.

From alumina, iron is separated by adding to the solution of the bases in hydrochloric acid, neutral tartrate of ammonia, and then caustic ammonia, until the reaction is distinctly alkaline. If any turbidity appears, more tartrate of ammonia is added until all dissolves. Hydrosulphate of ammonia is now poured into the clear liquid until its smell predominates. The whole is now heated upon the sandbath. The precipitate of sulphuret of iron is washed with water containing hydrosulphate of ammonia; at the commencement of the process, a little tartrate of ammonia likewise.

Glucina is withdrawn from iron by treating the solution with excess of potash, which dissolves the former.

Magnesia is separated from iron as from manganese, but if the iron be abundant, the solution is saturated with ammonia, and the iron precipitated as a succinate.

From lime and strontia, iron is separated by ammonia, which does not precipitate the two former. The deposit of ferric oxide is filtered off, and the two earths separated as above. After igniting and weighing the iron, it should be examined for traces of earthy carbonates.

From baryta, iron is separated by sulphuric acid. When iron occurs along with the alkalies it is precipitated by ammonia.

When the two oxides of iron occur in combination, their determination is highly difficult, and if the compound be insoluble in acids, impossible. If only compounds of iron be present (*e. g.* magnetic iron ore), the mass is dissolved in hydrochloric acid, nitric acid is added in order to peroxidize the protoxide, the liquid is diluted with water, and precipitated with ammonia, and the precipitate finally washed, dried, ignited, and weighed. From the increase of weight, the amonnt of oxygen absorbed to convert the protoxide into peroxide becomes known, and hence the relative proportions of the two oxides are calculated, when, as is frequently the case, the amount of protoxide is inconsiderable. The least error in the operation will render the result totally worthless.

If the mixed oxides be combined with phosphoric acid, a weighed quantity is dissolved in muriatic acid, and boiled to expel atmospheric air from the flask. A weighed blade of copper is introduced, and the boiling continued until the colour of the liquid shows that it contains merely a protosalt. The copper is dissolved and converted into a chloride. The liquor is mixed with boiling water, the blade of copper withdrawn, washed with hot water, dried, and weighed. The loss represents two equivalents of copper for each equivalent of peroxide of iron in the solution. To determine the protoxide, a fresh quantity of the ore is dissolved in muriatic acid, and a current of chlorine gas passed through the solution, excess being expelled by boiling. A blade of copper is now inserted, and the former process repeated. The difference between the two operations gives the amount of protoxide.

ZINC.

Zinc is precipitated from its solutions by carbonate of soda, ammoniacal salts if present being previously decomposed by heating with carbonate of soda. The carbonate of zinc, on strong ignition, leaves pure oxide, which is weighed. Zinc may also be thrown down as sulphuret by the hydrosulpate of ammonia from neutral solutions. The precipitate must be allowed to settle, and the clear liquid decanted as far as possible. The precipitate is then redissolved in muriatic acid, freed from HS by digestion, filtered, and reprecipitated by carbonate of soda. From iron, zinc is separated by dissolving the oxides in muriatic acid, avoiding excess, and adding, in the cold, an excess of carbonate of baryta, thoroughly mixed. The precipitate is dissolved in muriatic acid, and any excess of baryta precipitated by sulphuric acid.

From manganese, zinc is separated by neutralising the acid of the solution with carbonate of soda, and cyanide of potassium

and carbonate of soda added in excess. When boiled, the manganese is precipitated.

Zinc is withdrawn from zirconia, ceric oxide, yttria, thoria, and glucina, by converting them into sulphates, adding free acetic acid, and precipitating the zinc as HS.

Oxide of zinc and alumina are separated by dissolving them in a large excess of potash, or converting them into acetates, and in either case precipitating the zinc as sulphuret with HS.

The treatment of *gahnite*, a native compound of zinc and alumina, insoluble in acids, will be given below.

From magnesia, zinc is separated by HS, the oxides being previously converted into acetates.

The same method is applied to lime; or, the mixed solution is treated with ammonia, and hydrosulphate of ammonia added. The precipitate is filtered rapidly, out of contact of the air.

Strontia is treated in the same manner.

Baryta is withdrawn from zinc by means of sulphuric acid.

Zinc may also be separated from lime, strontia, and baryta, by adding carbonate of potash in slight excess, then cyanide of potassium. When heat is applied the zinc dissolves, while the earths remain insoluble. To the filtrate, nitro-muriatic acid is added, and the whole boiled until the cyanides are decomposed, when the zinc is precipitated in the usual manner.

CONCHOLOGY.

CHAPTER VIII.

ORDER V.—GASTEROPODA.

Animals with the body straight, never spiral, nor totally enveloped in their shell; the foot or disc situated under the belly, and united to the body nearly its whole length, and serving as an organ of locomotion.

GRAND DIVISION I.—PNEUMOBRANCHIÆ.

Branchiæ in the form of a vascular net, on the wall of a particular cavity, opening by a hole which the animal contracts or dilates at pleasure. They respire air.

TRIBE I.—BULLACEA.

Shells greatly distended, and without any apparent columella.

Genus.—Bulla.—*Linnæus.*

Generic Character.—Shell convolute, oval, with a depression above in place of a spire; aperture longitudinal, as long or longer than the convolutions, straitened above and expanded beneath, where it is effuse; outer lip thin; columellar lip generally reflected with a coating of shelly matter.

Bulla attenuata. Plate VI. fig. 1.

The Bullæ are marine shells common to tropical climates, as well as to almost all countries. Several inhabit the British seas.

Sowerby has united the *Bulla* and *Bullæa* of Lamarck, in which we have followed him.

The fossil Bullæ are found in the Tertiary formations, and in the Green Sand.

Genus.—Utriculus.—*Brown.*

Generic Character.—Shell small, oblong-ovate; body very large, spire very short, with rounded volutions; aperture as long as the body, narrow above, wide, and rounded at the base; outer lip thin and slightly inflected; inner lip not reflected on the columella.

Utriculus glaber. Plate VI. fig. 7.

The shells of this genus are marine, the recent type of the genus is the *Bulla retusa* of Montagu. Fossil species occur in the Oolite at Cloughton and Brandsby, and in the inferior Oolite at Cloughton.

The shell we have figured is the *Acteon glaber* of Phillips, but it is inadmissible into that genus, being destitute of a fold on the columella.

TRIBE II.—CALYPTRACEA.

The branchiæ of the animal situated in a dorsal cavity near the neck, and included in the cavity, or projecting beyond its shell, which is invariably exterior.

Genus.—Ancylus.—*Müller.*

Generic Character.—Shell thin, obliquely conical, patelliform; vertex somewhat pointed, short, turned backwards, and slightly inwards, but not spiral; aperture oval or oblong, with the margins simple and entire.

Ancylus elegans. Plate VI. fig. 25.

Two recent species of this genus inhabit the fresh waters of Europe, and both are natives of Britain. They differ from the Patellæ in the apex being turned backwards.

Fossil species occur in the *Calcaire-grossier.*

Genus.—Dentalium.—*Linnæus.*

Generic Character.—Shell symmetrical, cylindrical, forming a lengthened curved tube; its anterior orifice open, without constriction, to the greatest breadth of the shell; the posterior extremity attenuated and perforated; surface smooth or annulated, or longitudinally ribbed or striated, or with decussating striæ.

Dentalium Costatum. Plate VI. fig. 31. Found in the Coral and Red Crags at Sutton. Shells of this genus are found in the present seas, viz., in Britain, and most other portions of the globe.

Genus.—Calyptræa.—*Lamarck.*

Generic Character.—Shell conical, vertex subcentral, imperforate and acute; base or aperture orbicular, or nearly so, its margins sharp and entire; internal cavity provided with a lateral salient appendage or septum, which varies much in form in different species: various species have a strongly-marked muscular impression, just above the fold of the inner lip; in other species, it is situate on the outside of the inner cup, but never within it.

Calyptræa trochiformis. Plate VI. figs. 12 and 21. *C. rectum.* Plate VI. fig. 23.

The internal appendage varies much in form; in some it is tongue-shaped, emanates from, and is fixed near the summit, with both edges turned inwards; in others it is small, and irregularly triangular, attached by its largest side to the internal cavity of the shell; in other species it is cup-shaped; in another division, this consists of a spiral plate, reflected at the upper part, so as to form an umbilicus. They are mostly thin shells, with the outside either smooth or covered with spinose points or murications, radiating or concentric striæ or ribs. The outside is invested externally with a thin epidermis. They are subject to great variety of form, arising from their being stationary, and taking the shape of the substances to which they attach themselves.

The genus does not consist of many species, they are all marine, inhabiting the shores of America and South Seas; one species, the *C. sinense*, is a native of Britain.

Fossil species occur in the *Calcaire-grossier* at Paris, and London Clay.

Genus.—Pileopsis.—*Lamarck.*

Generic Character.—Shell obliquely conical, posteriorly recurved, with an uncinate spiral apex, the volutions serrated and rolled inwards; aperture large, ovate, anterior margin shortest, the posterior one large and rounded, inside with two elongated, arcuated, muscular impressions, situated under the posterior margin; external surface covered with a thick, horny, somewhat pilous epidermis.

Pileopsis vetusta.—Plate VI. fig. 17. Found in the Black Limestone, Queen's County, Ireland.

The species of this genus are marine and few in number. They inhabit the Pacific Ocean, East and West Indies, Europe, and one species, the *P. ungarica*, is a native of the British seas. They are found in deep water, adhering to oysters and stones.

Several species are found fossil in the Tertiary formations.

Genus.—FISSURELLA.—*Bruguière.*

Generic Character.—Shell oblong, shield-shaped, or conically depressed; concave within; destitute of spiral convolutions, but with the vertex perforated, and directed towards the front of the shell; the perforation is subovate or nearly round; margin of the shell thickened around the inside, and generally crenulated; muscular impression visible near the inner edge all round, widest on the sides near the front; outer surface striated, grooved, or radiated from the vertex to the margin, and generally decussated by lines of growth.

Fissurella græca. Plate VI. figs. 19 and 24. Found in the Crag at Ipswich.

This is a genus of marine shells, and consisting of nearly forty species. They inhabit the seas of every quarter of the globe, and one species is found on the British coasts.

A few fossil species have been found in the marine formations above the Chalk.

Genus.—SIPHO.—*Brown.*

Generic Character.—Shell subconic, vertex reflected, and slightly spiral, with a small dorsal fissure near the apex, terminating interiorly by a rhombic funnel-shaped siphon; base ovate.

Sipho clathrata. Plate VI. fig. 5. Found in the Oolite at Ancliffe.

They inhabit the sea, and one species, the *S. striata*, has been found in the Clyde, and in a sub-fossil state, in a raised beach at Dalmuir, near Glasgow.

Genus.—EMARGINULA.—*Lamarck.*

Generic Character.—Shell conical, shield-shaped; vertex inclined to the posterior extremity; anterior margin with a fissure, or notch; internal cavity simple; anterior sides of the muscular impression interrupted, expanded, and not continued across the front.

Emarginula tricarinata. Plate VI. fig. 13.

Sowerby has, in our opinion, most improperly reunited this genus and Parmophorus. Both genera have peculiarities of structure, by which they may at once be recognised, and consequently the reunion must tend to confound, rather than improve the arrangement.

The species of Emarginulæ do not exceed four or five; they are marine shells, and inhabit the seas of almost all climates; one of them, *E. fissura*, is a native of the British coasts.

Fossil species are not plentiful, they occur in the *Calcaire-grossier* at Grignon, and other contemporaneous formations; also in the Crag of Essex, Norfolk, and Suffolk, and the Bath Oolite.

TRIBE III.—PHYLLIDIACEA.

The branchiæ of the animals situated beneath the margin of the mantle, in a longitudinal series around the body; they respire in water. Shell simple.

Genus.—CHITON.—*Linnæus.*

Generic Character.—Shell elongate, or oblong-oval, consisting of eight valves, placed transversely on the back of the animal, which is convex; these valves are moveable and imbricated, the lower edge of each resting on that below it; the terminal valves rounded exteriorly; all these are surrounded and attached on their external sides to a coriaceous mantle, forming a marginal skin or border; several of these valves are provided with marginal notches or teeth, which are however concealed in the marginal border, which is either smooth, shagreened, granulated, wrinkled, or spiny.

Chiton rissoi, Plate VI. fig. 32, being the primal valve, fig. 33, the central valve, and fig. 34, the terminal valve. Found in the Coral Crag, Sutton. Fig. 35, *Chiton marmoreus*, a recent British species, to illustrate the perfect shell.

Genus.—PATELLA.—*Linnæus.*

Generic Character.—Shell ovate or oblong, more or less of a conical form, sometimes, although rarely, pyramidal; vertex rarely central, generally placed anteriorly, with its apex inclined towards the head of the animal; concave within, and the margin entire; muscular impressions distinct, and same form as the shell, placed about half way betwixt the summit and the margin, interrupted in front, where the head of the animal is situated; external surface striated or ribbed, in a variable manner, from the apex to the base; in the latter case, the margin is variously dentated or crenulated.

Patella striata. Plate VI. fig. 20. Found in the London Clay at Stubbington, and at Valognes and Hautville, France.

This is a marine genus, consisting of numerous species, for the most part subject to great variety of form, depending on the local situation in which they are placed. They are met with on the coasts, adhering to stones and rocks. Their geographical range is very wide, being found in almost all climates.

Fossil species are, however, not common, and occur only in the Great Oolite, the *Calcaire-grossier*, and in the Crag of England.

Genus.—METOPTOMA.—*Phillips.*

Generic Character.—Shell subconical, depressed; vertex subcentral; face under the apex truncated, general form somewhat shield-shaped.

Metoptoma pileus. Plate VI. fig. 16. Found in the Mountain Limestone Bolland.

The shells of this genus are entirely fossil, and are at once distinguished from the Patellæ by their truncated end.

CLASS SECOND.—BRACHIOPODA.

The oval arms are elongate, regularly spirally twisted when in repose.

The Brachipods are a well-defined group of shells, and by their now well classified divisions throw much light on geological revolutions. Productæ prevail from some of the oldest strata to and into the magnesian limestone; Spiriferæ, commencing in as early periods, are met with in the lias; Terebratulæ, equally ancient, are also found through the secondary and tertiary periods, and exist in our present seas.

On a careful examination of the Terebratulæ of the strata below the lias, it will be found that but few examples are met with of species exhibiting a distinct oval or circular opening below the beak, (such as belongs to the *Terebratula concinna*,) and perhaps none which show a truncated perforate beak, (as in *T. maxillata*,) structures which are common mezoic and cainozoic rocks, as well as in the existing seas.

Recent investigations have shown that this order, comprehending many discordant species, required remodelling since the time of Lamarck. Gray has elevated this order to the rank of a class.

ORDER I.—SARCICOBRANCHIA.

The oval arms fleshy, without any shelly support.

TRIBE I.—LINGULIDÆ.

The shells of this tribe are more or less elongated longitudinally, pointed at the beaks, subequivalve, regular, covered with an epidermis, and attached to marine bodies by a peduncle passing out between the beaks of the valves. The branchial system differs somewhat from that of other known Palliobranchs, in consisting, though perhaps only partially, of slightly-developed tufts or processes originating from the great pallial vessels.

Genus.—LINGULA.—*Bruguière.*

Generic Character.—Shell equivalve, equilateral, oblong-ovate; compressed; thin; acute and gaping at the umbones; slightly truncated or trilobate at the base; muscular impressions situate towards the centre of the valves; external surface covered with a glossy, thick epidermis; hinge destitute of teeth; shell suspended by a cylindrical fleshy tendinous pedicle attached, which issues between the umbones, provided with a groove for its passage in that of the larger valve; two muscular impressions in one valve and four in the other.

Lingula mytilloides. Plate VII. fig. 1. Found in the Carboniferous Limestone at Wolsingham, county of Durham.

When the valves of this shell are closed, they are compressed, and have much the appearance of a duck's bill. They are attached to each other by the internal muscles. They vary considerably in their internal and external conformations; one valve having in its interior an elongated projection between the two muscular impressions, lying in a longitudinal direction; the other valve is destitute of this, and also wants the testaceous matter at the points of the valves.

The recent species of Lingulæ are few, and inhabit the Mollucca islands.

Fossil species of Lingulæ are found in the sandy indurated marl at Bognor, in the carboniferous limestone of Durham, in the shale of the Vale of Todmorden, and in the lowest Silurians at Tremadoc, North Wales; and is perhaps the most long-lived genus with which palæontologists are acquainted. But, nevertheless, it is remarkable, that it has never, during any period, been represented by more than a few species.

TRIBE II.—DISCINIDÆ.

The upper valve is conical and patelloidal, the lower valve orbicular and flat, and is attached to marine bodies by a short tendinous pedicle, which passes out through a slit in the posterior part of the disc of the ventral valve.

Genus.—PYCNODONTA.—*Fischer.*

Generic Character.—Shell inequivalve, transverse, equilateral; hinge arcuated, extending considerably, and ending in subauriform lobes; numerous small, close-set, curved, lamelliform teeth, with a transverse ovate pit at the centre for the reception of the ligament; beaks small, and but slightly produced.

Pycnodonta radiata. Plate VII. fig. 2.

Genus.—CRANIA.—*Retzius.*

Generic Character.—Shell inequivalve, suborbicular, mostly equilateral, slightly irregular; upper valve patelliform, very convex, interiorly provided with two projecting callosities, its umbo placed rather behind the centre; lower valve adherent, nearly flat, pierced on its end or surface with three unequal and oblique holes; each valve with four muscular impressions; two of those in the upper valve are situate near the posterior margin, the other nearer the centre, but always close to each other; in the lower valve two are almost marginal and remote, but the other two are nearly central, and so close together that they seem united, with usually a small projection between them; destitute of a hinge. Animal without a byssus.

Crania striata. Plate VII. figs. 12, 13.

The lower valve in this genus is exceedingly variable in thickness; in some species it is so thin that it is hardly observable; yet this valve is the most characteristic of the genus; it has the property of adhering to other substances by its own surface; it is wholly destitute of a hinge, teeth, or ligament. It has four strong impressions, by which the tendinous muscles are attached, and by which it is at once united to the animal and the upper convex valve; two of these muscular impressions are situate at a distance from each other, near the margin, which is usually nearly straight between them, the others are towards the centre of the disc, merely separated from one another by a slight prominence in the under valve, while they are more remote in the upper valve; the inner surface, particularly about the margin, is granulated; produced from the structure being cellular, instead of foliaceous. The vertex of the upper valve is nearly central; it is generally thin in substance, and presents the same granulated surface near the margin as the lower valve, although not quite so conspicuous. The cellular structure of the shells of the genus *Crania*, at once serve as an unvarying mark whereby to distinguish them from all other genera. They also differ from *Hipponyx*, in having four muscular impressions in place of two.

The Craniæ are marine shells, and very limited in number; they inhabit the Mediterranean and British seas.

There are only five or six fossil species of this genus; and these are found in the *Calcaire-grossier* near Paris; one at Népou, department of la Manche, another at Mendon, and one also in Sweden.

Genus.—THECIDIUM.—*Defrance.*

Generic Character.—Shell inequivalve, somewhat irregular, and nearly equilateral; umbones acute, imperforate; attached by the outside of the convex valve; lower valve provided with two internal, short cardinal processes, and an external triangular area, rather irregular in its form, and extending to the umbo; upper valve somewhat flattened, with a small, short obtuse appendage, situate externally, at its base; furnished with two small lateral cardinal processes internally, and with variously curved laminæ, invariably adhering to the inner disc of the valve; hinge destitute of a ligament, but the valves are kept together by the attachment of the lateral processes.

Thecidium recurvirostrum. Plate VII. figs. 6, 7, 8.

The shells of this genus have considerably the aspect of several of the Terebratulæ, but may at once be distinguished by their being devoid of an umbonal perforation in the convex valve, which is an invariable characteristic of that genus.

This is a marine genus, and fossil species have been found in the Chalk of Orglandes, in Normandy, and at Maestricht.

Genus.—SPIRIFER.—*Sowerby.*

Generic Character.—Shell transverse, equilateral, inequivalve, more or less trigonal and convex; hinge straight, linear, widely extended equally on both sides of the umbones, which are more or less remote, being separated by an intermediate flattened area, varying considerably in breadth, in different species, and consists of three triangular parts, a central and two lateral ones; this area is divided in the centre by a triangular pit for the passage of the byssus; within the smaller valve, and near the umbo, two spiral testaceous appendages are attached, whose convolutions diminish in size as they diverge from the centre of the shell; hinge straight, transverse, formed of two diverging teeth, limiting the base of the deltoidal fissure of the larger valve, and placed in the sockets existing on each side of the beak of the smaller valve.

The central part seems to have been an aperture for the passage of a byssus, by means of which the animal probably attached itself to rocks and stones in the sea.

Spirifer cuspidatus. Plate VII. fig. 23. Figs. 22, 24, and 25, represent the two spiral appendages.

No recent species of the Spirifer are known, being only found in a fossil state. They are very numerous, and abound in the Mountain or Carboniferous Limestone, the Transition Limestone, and the Old Red Sandstone; but none of them have been met with above the Magnesian Limestone; most of the species are ribbed, grooved, or striated externally.

Attention to the area between the beaks, and their internal spiral appendages, will at once distinguish the shells of Spirifer from the Terebratulæ, to which they are somewhat allied.

This genus is properly divided into six sections by Professor Phillips.

Section 1. *Cuspidatæ.* Beaks imperforate, separated by a wide triangular area, the lower one not incurved; upper valve convex; hinge line generally straight, and equal to the breadth of the shell.

Section 2. *Augustatæ.* Cardinal line as wide as the shell; valves with incurved beaks; mesial fold defined between two deeper furrows on the upper valve.

Section 3. *Radiatæ.* Cardinal area not so wide as the shell; surface radiated.

Section 4. *Glabratæ.* Cardinal area not so wide as the shell; surface plain.

Section 5. *Terebratuliformis.* Devoid of a cardinal area.

Section 6. *Filosæ.* Surface with prominent radiating threads.

Genus.—GYPIDIUM.—*Dalman.*

Generic Character.—Shell inequilateral, inequivalve, the larger valve with an incurved umbo, remote from the hinge; the larger valve divided by a central septum into two parts; the other by two parallel approximate septa into three unequal parts; umbones imperforate and incurved. The septa

consist of short fibres which meet in the middle, so that each septum may be easily divided into two.

Gypidium aylesfordii. Plate VII. fig. 10. Found in the Dudley Limestone, and is a characteristic member of the Silurian rocks.

This genus was established by Sowerby under the name of Pentamerus, but as that name is preoccupied by a genus of insects, we have adopted the name of Dalman, who also denies that the shells of this genus are quinquelocular.

Genus.—Magus.—*Sowerby.*

Generic Character.—Shell inequivalve, equilateral; one valve convex, provided with an angular sinus along an incurved beak; line of the hinge, and back of the other valve straight, with two projections near the centre; a partial longitudinal septum attached to the hinge within.

Magus pumilus. Plate VII. fig. 11.

This genus has much the general form of some of the smooth Terebratulæ, but will readily be distinguished from the shells of that genus by an examination of the parts about the hinge. The beak is destitute of perforation, but there is a large quadrangular foramen, two sides of which are formed by two ridges from the straight back of the depressed valve, and other two run along to the point where they meet; on the side of it there is a flattened space, emanating from the hinge line, which is considerably longer than the foramen, and terminates in the apex. On separating the valves, the foramen is divided into two angular sinuses, that in the beaked valves being considerably larger than the other. A thin longitudinal septum is situate in the middle of the shell, reaching from one valve to the other, the upper part of it extending in an arcuated form over the hinge, and having a perpendicular front, with two shelf-like appendages, placed one above another, the upper ones attached by slender testaceous processes to the hinge.

Known only in a fossil state, and is found in the Chalk near Maudesley, Norwich, and but one species has been discovered.

Genus.—Terebrirostra.—*D' Orbigny.*

Generic Character.—Shell inequivalve, equilateral; subtrigonal; one valve generally more convex than the other; one of them prolonged into a lengthened beak, truncated at the point, and perforated for the passage of a tendon, by which the animal attached itself to extraneous bodies; hinge destitute of a ligament, but provided with two teeth, in one valve, which lock into corresponding cavities in the other; two muscular impressions, situate near the centre of both valves.

Terebrirostra lyra. Plate VII. fig. 20.

Found in the Greensand of Chute Farm, near Horningsham.

This is exclusively a fossil genus, which is formed of *Terebratura lyra* of Sowerby, and other corresponding species.

Genus.—Trigonosemus.—*Kœnig.*

Generic Character.—Shell inequivalved, irregularly oval, circular, or rhomboidal, as wide as long, or longer than wide; larger valve always convex; smaller valve moderately so, flat or longitudinally depressed, beak produced, more or less recurved, and truncated by a small, oval, elongated foramen, beginning at the summit of the beak, and directing itself on the opposite side to the area. Area large, often nearly as wide as the shell, triangular, flat-edged and carinated exteriorly; deltideum occupying less than a third of the surface, a small portion only surrounding the foramen surface, ornamented by numerous small radiating costæ, augmenting by intercalation at variable distances from the beak and umbo. Hinge line very obtuse, sometimes straight; valves articulating by means of two teeth in the larger and corresponding condyles in the smaller valve; between the latter a remarkably developed bos, or cardinal muscular fulcrum, extending in some species considerably beyond the hinge line, and filling a corresponding cavity in the beak of the larger valve; a short, thick, elevated, longitudinal septum occupies about half of the length of the valve, and on either side of which are two deep, oval, muscular impressions; apophysary system or loop doubly attached; the riband-shaped lamella are first fixed to the sides of a cardinal muscular fulcrum, and after proceeding to a short distance, are again attached to the highest point of the septum, before bending back on themselves to form the loop.

Trigonossimus elegans. Plate VIII. fig. 40.

Found in the Cretaceous formations.

Genus.—Orthis.—*Dalman.*

Generic Character.—Shell inequivalve, with a rectilinear hinge; umbones distant; larger valve with a transverse smooth area, and a triangular pit.

Orthis canalis. Plate VII. fig. 14.

Found in the Wenlock Shale, which is a member of the Silurian series.

Distinguished from Spirifer by the long narrow hinge, and circular flat form of the striated shells. They abound in the lower Palæzoic strata, and become somewhat rare in the upper portions of the Carboniferous limestone.

Genus.—Leptæna.—*Dalman.*

Generic Character.—Shell equilateral and inequivalve; one valve being convex for the most part, and very rarely somewhat depressed; its anterior edge rounded, very thin, bent downwards, and produced into an irregularly cylindrical form, a little expanded towards its lower edge, the opposite valve is usually flat, or slightly concave on the outside, with its anterior margin reflected, so that its inner edge lies against the inside of the concave valve; the cardinal margin is transverse, parallel and linear, sometimes so much produced on both sides as to give it a winged appearance.

Leptæna scarbiculus. Plate VIII. fig. 40.

No remains of a ligament have been noticed, but there have been observed indications of internal processes near the hinge of the depressed valve; like all the other Brachiopods, the texture is granose within, with the external surface frequently spinose. The shell possesses a very singular peculiarity; namely, that of its anterior margin being produced beyond that part occupied by the animal.

The shells of this pretty numerous genus are known only in a fossil state, and are peculiar to the strata of the secondary formation, and which they in a great measure characterize; more especially the Carboniferous limestone; they are also met with in the older Transition limestone, the Seatoschist of Snowden, and the Magnesian limestone of Breden, Derbyshire.

I have adopted this generic name instead of *Producta* of Sowerby, as it is ungrammatical.

Genus.—Cyrtia.—*Dalman.*

Generic Character.—Shell longitudinal, inversely pyramidal, inequivalve, subequilateral; one valve considerably depressed, the other convex; hinge-line rectilinear; beaks in one valve only, and slightly incurved.

Cyrtia cuspidata. Plate VII. fig. 28.

Found in the Carboniferous limestone, St. Vincent's Rock, near Bristol.

This genus consists exclusively of fossil species. Our type of the genus is *Spirifer cuspidatus* of Sowerby.

Genus.—Atrypa.—*Dalman.*

Generic Character.—Shell longitudinal, equivalve-equilateral; hinge-line slightly curved, umbones small, and not incurved.

Atrypa reticularis. Plate VII. fig. 9.

Distinguished from its congeners by its short hinge-line, and in being destitute of a large area; likewise in having no foramen, or only a small triangular one.

Genus.—Composita.—*Brown.*

Generic Character.—Shell somewhat pentangular; wing area very short; beak of the larger valve produced, with a small circular perforation; inside furnished with spiral appendages.

Type.—*Spirifer ambiguus*, Sowerby. Found in the Carboniferous limestone.

Genus.—Terebratula.—*Braguière.*

Generic Character.—Shell inequivalve, equilateral, generally

trigonal and gibbous; attached by a short peduncle to extraneous marine bodies; the larger or upper valve, with a projecting umbo, frequ ntly bent, and perforated at its apex, or notched at its inner edge, and having a small curved tooth on each side of its hinge, which fits into a corresponding pit in the opposite valve; the inside of the smaller valve is provided with two slender testaceous processes, which are sometimes simple, short, and recurved; at others considerably elongated, branched, bent in various directions, and anastomosing for the most part; sometimes they are situate near the centre of the valve, and in other instances are united by their points to the shell; these usually emanate from each side of the hinge; both valves provided with two nearly obsolete muscular impressions, but sometimes they are strongly developed; those of the larger or perforated valve are oblong, central, and close to each other; in the smaller valve they are triangular, with their angles rounded, also nearly central, but more distant than in the other valve.

Terebratula semiglobosa. Plate VII. figs. 15, 16.

The Terebratulæ are Oceanic shells, adhering to extraneous substances. They are very numerous, and inhabit the seas of all countries; two or three are natives of the British seas. They are subject to considerable variety in form and markings.

Fossil species are still more numerous than the recent ones. They are of the utmost importance to geologists, as they occur in all the Secondary and Tertiary strata, commencing with the earliest, excepting those of fresh-water origin, and they have never been detected in the upper marine formation. Particular species distinguish certain strata.

Section 1. Smooth, generally oblong; the middle of the front even or depressed.

Section 2. Plaited, generally oblate; the middle of the front even or elevated.

Section 3. Adhering to marine bodies by their flattened valve.

Genus.—ORBICULA.—*Cuvier.*

Generic Character.—Shell inequivalve, nearly orbicular, compressed, generally irregular in form, adherent, flat, and attached by means of a fibrous substance passing through an orifice near the centre of the lower valve; upper valve patelliform, its vertex posterior or nearly central; each valve provided with four muscular impressions, two of which are large, approximate, and situate near the centre, and two smaller and more distant placed near the posterior margin; those of the lower valve not so well defined as the others; near the inner extremity of the orifice there is an obtuse testaceous process; destitute of hinge teeth or a ligament.

Orbicula granulata. Plate VII. fig. 20. Found in Argillaceous Ironstone nodules in Alum Bay, Isle of Wight.

The Orbiculæ are oceanic shells, consisting of only two or three species, inhabiting the European seas.

Fossil species are limited, and met with in the Coral Oolite of Yorkshire, the Great and Inferior Oolite of Wiltshire and Yorkshire, the Lias of Northamptonshire, and the Coal Measures of Coalbrookdale.

TRIBE II.—RUDISTA.

Animal unknown, as are also the ligament and hinge; shell with very unequal valves, and destitute of distinct umbones.

Genus.—HIPPONYX.—*Defrance.*

Generic Character.—Shell bivalve, adherent, inequivalve, irregular; muscular impressions in both valves horse-shoe shaped; lower valve affixed to marine bodies, orbicular, much compressed, and considerably thickened in some instances, with its margins always elevated, particularly in front, its muscular impression consisting of two contiguous semilunar portions, which are distant, broad and rounded in front, nearly confluent and narrow behind; upper valve patelliform, generally subconic, in some instances compressed, with a posteriorly submarginal umbo pointing backwards; muscular impression situate near the posterior margin, with its two lobes considerably more remote and obliquely truncated in front, but entirely confluent behind; hinge destitute of a ligament or teeth.

Hipponyx cornucopiæ. Plate VII. fig. 4, upper valve; and under valve, fig. 5.

The fibres in the muscular impressions are placed in a different direction from those of the other portions of the shell, and seem to be more liable to decomposition. In fossil species these present cavities.

One species only is known in a recent state, namely, the *Hipponyx mitratus*, which inhabits the West Indian Seas. Several fossil species have been detected in the Calcaire-grossier of France.

The *H. mitratus* was, until lately, considered a univalve, and has been figured and described as *Patella mitrata.* The fossil species have been also included by Lamarck among his Patellæ.

Genus.—CALCEOLA.—*Lamarck.*

Generic Character.—Shell equilateral, inequivalve, triangular; umbones separated by a large, depressed, irregularly and transversely striated, trigonal area in the lower valve, which is the larger of the two, and very deep, funnel-shaped, and obliquely truncated at its upper side; hinge margin transversely straight, linear, notched, and slightly toothed in the centre; the upper edge arcuated; upper or smaller valve semiorbicular, semicircularly striated, and serving as a lid to the lower valve; internal cardinal edge furnished with two lateral tubercles, a central pit and smaller plate.

Calceola sandalina. Plate VII. figs. 26, 27.

The very peculiar form, and other characteristics, of the Calceola, distinguishes it from all other bivalves; namely, its great thickness and solidity, its being striated internally, from the centre to the circumference, and being destitute of a ligament. In general form it has much the appearance of a lady's slipper. It is supposed to have been attached by the beak or umbo of the larger valve.

There is but one species of this genus, and it is fossil, found in the neighbourhood of Juliers in the Mountain Limestone. The only fossil to which the Calceola bears the slightest resemblance is *Spirifer cuspidatus.* Plate VII. figs. 8, 9, 10.

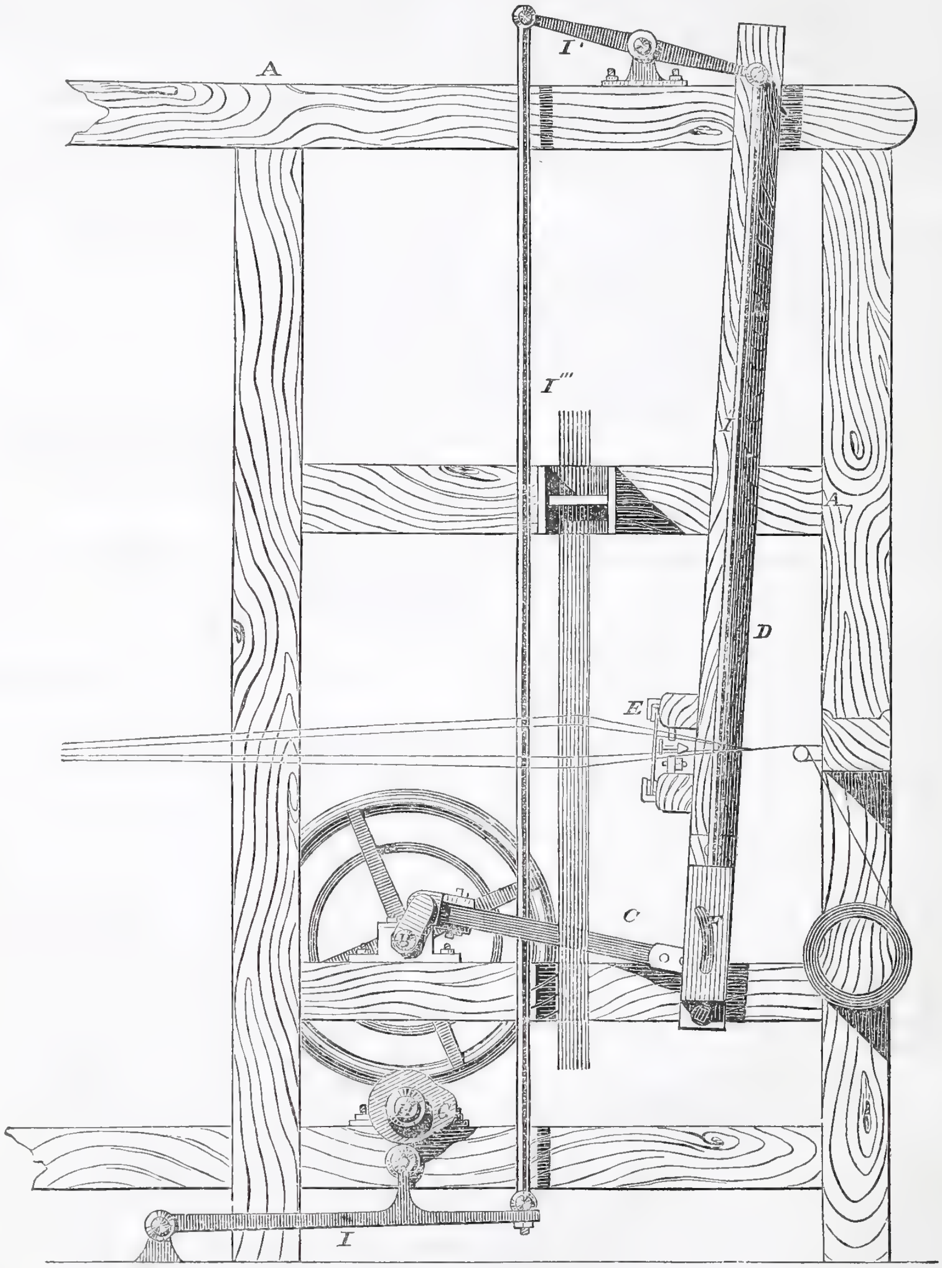
PATENT TAPESTRY CARPETING.

THIS description of carpeting is manufactured under the patent of Mr. R. W. Sievier of London. The invention is of a twofold character, the first part having reference to the mode of forming the loop in terry or raised fabrics, and the second part relating to the arrangements for adapting the loom to weave fabrics in which the loop is raised in the improved manner.

The first of these improvements consists in forming the loops or terry without the aid of pins or wires, over which the terry threads pass according to the ordinary method, but the loops are formed by the weft threads not being always closely beaten up, as follows:—When the loops are to be formed, the next pick of the weft is not closely beaten up by the reed, but a considerable interval of space is left between this pick, or shoot, and the pick immediately preceding it, and which had been fully beaten up. Several of the succeeding picks of weft are now beaten up closely to the last, still leaving the interval of space unoccupied; and when a number of picks or shoots have been thrown, the whole of them are then beaten up by increased action of the reed; the interval of space before spoken of is filled, and the loops are raised; but to accomplish this object, the terry warp is slackened, which enables the weft, when beaten up, to carry with it the terry warp, and thus cause that portion of the terry warp threads which were in the interval of space to be puckered up into loops; at the same time that the terry warp threads are slackened, and the increased beating up takes place, the draw and binding warps are held and secured fast to prevent their moving up to the picks of weft when beaten up, whereby the picks of weft slip over these warps, and no puckering or loops are formed with them.

The second part of the invention consists in the adaptation of the parts of the loom for effecting the increased and decreased distance beaten up by the reed; this is illustrated by our engraving, which is a side elevation of a portion of a carpet loom: A A the loom framing, B the crank shaft, C

the connecting rod, D the swords of the slay, E the slay or reed. The ends of the connecting rods, C, where attached to the swords of the slay, are capable of being elevated or depressed, so as to alter the distance to which the reed is driven. Thus, when the ends of the connecting rods are at their lowest point at the bottom of the slots, F, then the traverse of the reed will be less than when the point of attachment is at the top of the slots. A cam wheel, G, upon the tappet shaft, H, effects, through the levers, I and I′, and the rods, I″ and I‴, the requisite elevation and depression of the ends of the connecting rods. The mode of operation is as follows:—Supposing the ends of the connecting rods are at their most elevated position upon the swords, D, the reed will then beat up the preceding picks of weft closely; but as the terry loops have to be formed, the ends of the connecting rods are, by the action of the apparatus, lowered to the lower part of the stop;



this has the effect of decreasing the distance traversed by the reed, whereby the next pick or shoot of weft to be beaten up is not beaten close up to the preceding pick, but an interval of space is left between the picks, proportionate to the traverse of the reed; the succeeding picks of weft are beaten up close to the first, until the action of the cam, G, again raises the ends of the connecting rods to the upper ends of the slots; when the distance of traverse of the reed will immediately be increased, and the next beat up will carry the whole of the preceding picks of weft onwards, and close to the preceding portion of the fabric, filling up the interval of space before formed. At the moment of the reed making this last beat up, the terry warp is slackened, which will be carried forward by the picks of weft, and that portion in the interval of space will be puckered up and the loops formed; at the same time the draw warp and the binding warp will be held back, so that the picks of weft will slide over them when the increased beating up takes place. This being done, the ends of the connecting rods are again depressed to their former situation, when at the next beating up an interval of space is left as before described.

THE EARLY HISTORY OF PRINTING.

Foremost of the mechanical arts which promote the prosperity of man, is Printing. There is none which has exercised, or will probably exercise, a more beneficial influence upon him than this. There is none which affords him greater help in lessening the evil of his lot. What activity it has given to thought—what a light it has thrown upon the dark places of the world—how rapidly and how widely it has spread the seeds of knowledge—what a comparative stability it has given to language! "What diverse effects this new invention of printing hath produced," was a remark of Cardinal Wolsey, and every year since his time has given occasion for a repetition of the same observation. At the dawn of so much enlightenment, the moles and bats might well be alarmed, and declare that *they must root out printing, or printing would root out them.* Thus Andrew Marvell expressed the sentiments of such persons in a cutting strain of irony—"It was a happy time when all learning was in manuscript, and some little officer did keep the keys of the library. There have been wayes found out to banish ministers, to find not only the people, but even the grounds and fields where they assembled in conventicles; but no art yet could prevent these seditious meetings of letters. Two or three brawny fellows in a corner, with mere ink and elbow grease, do more harm than a hundred systematic divines with their sweaty preaching. Oh printing! how hast thou disturbed the peace of mankind!—that lead when moulded into bullets, is not so mortal as when formed into letters!"

The origin of the art in the East is dated by some writers before the birth of Christ, and in China it is supposed to have been known in a rude way for three thousand years. "As the stone *Me* (a word signifying ink) which is used to blacken the engraved characters, can never become white, so a heart blackened by vice, will always retain its blackness." So said the emperor Van Vong, who flourished 1220, B.C. In all probability the printing thus alluded to, was done by the application of each engraved block to the paper by the hand. The Chinese, however, if they can be said to have possessed the art of printing, seem to have kept it to themselves, and like all hoarded wealth, it appears to have done its possessors little good. The dissemination of books must have been very slow as long as they were entirely produced by the hand and pen. Caxton uttered his complaints against the labour of transcription in these words:—"Thus end I this book, and for moche as in wryting of the same my penne is worn, myn hande wery, and myn eyne dimmed with over moche looking on the whyt paper, and that age creepeth on me dayly." Earlier than his time a few books had been executed from engraved blocks of wood, of which the earliest is dated in 1423, and contains the curious print of St. Christopher, alluded to in our article on Engraving (Vol. I. p. 317). The MSS. produced by the monastic scribes and others, were frequently richly ornamented with miniature painting, and the writers took delight in colouring (or miniaturing, as it has been called), the capital letters throughout. Such manuscripts as these are now stored up in museums as specimens of the industry and ingenuity of past times, when newspapers and magazines were not. Of course it was only the rich that could afford to buy books. We learn from a letter addressed by Bononia Becatellus to the king of Naples, that the price of a volume of Livy's works was 120 golden crowns, and that to purchase the whole he had to sell a piece of land. It is a fact, that a Countess of Anjou paid for a copy of the homilies of Harmon, bishop of Halbertstadt, 200 sheep, five quarters of wheat, and five quarters of rye.

There have been four principal competitors for the honour of having invented the art, namely, Gutenberg of Mayence, Fust, or Faust of Strasburg, Schoeffer of Gernsheim, and Costar of Haarlem. If ever any man deserved to be held in grateful remembrance by his fellows, it is the inventor of printing, but such was the ambiguous manner in which it came to light, and so little information is there upon which we can rely touching its early history, that the matter must, we fear, for ever remain shrouded in uncertainty like the beginnings of many other important things. However it is usually considered that Gutenberg, alias Gensfleisch, has the best claims to the invention. He settled at Strasburg about 1424, as a merchant, and about 1442, he produced some school-books, printed from types, and eight years afterwards he published a printed Bible, in the latin language, which has been commonly called the Mazarine Bible, because a copy was unexpectedly found about the middle of the last century, in the library of Cardinal Mazarine at Paris. In the meantime he had entered into partnership with Faust, which was dissolved by reason of some disagreement that occurred, and the two men set up business separately in Strasburg. In 1457, an edition of the Psalter was published by Faust and Schoeffer—in the preface to which, they assumed the credit of the new invention. To the latter has generally been assigned a contrivance by which the making of types was facilitated, namely, by forming punches of engraved steel, whereby matrices were struck, and then the types cast. As to Costar, so dubious and uncertain is the origin of this splendid discovery, it has been asserted that no such person existed. However, at Haarlem they have a different tale, and the current tradition is, that to beguile an idle hour, when strolling in a forest near Haarlem, he began to carve letters in the bark of a beech tree, and then took an impression of them. He then took a loose piece of wood and did the same thing, only he laid upon the characters a species of adhesive ink. With such rude materials as these, he produced a book in Flemish, but as he printed the leaves only on one side, he glued them in pairs back to back. He then tried metal types, and his experiments succeeded completely. It happened that amongst the persons he employed, there was one who disregarded the oath his master imposed, and having learned the secret of making moveable letters, he stole away secretly to Mayence. This was no other than the above-mentioned Faust. Whether we believe this story or not, true it is that the Haarlem people have raised monuments to their illustrious Costar, and celebrate an annual festival to his memory as the undoubted inventor of printing.

Gutenberg removed from Strasburg to Mayence, and having there procured an advance of money, he set up a press and issued a Latin Dictionary, a Bible, and some other works. The works of the printers were then stopped by the invasion of Adolphus, Count of Nassau, whose service Gutenberg entered, and we hear no more of him as a printer. Faust is reported to have gone to Paris to sell some of his Bibles, and to have died there of the plague, and the name of Schoeffer alone afterwards appeared on the books issued from that press. The popular story of Dr Faustus and the Devil, found in so many languages, is said to have taken its rise from this individual. It seems that the better to keep their invention secret, the old printers formed their types in the shape of written characters; but as they sold their books at a rate much less than the venders of manuscripts could possibly afford, (sixty crowns instead of five hundred, was the price asked for a bible), Faust was charged with having dealings with the evil one. Something peculiar in the colour of the red ink with which the books were ornamented was noticed, and straightway it was affirmed that it was the blood of the printer which the devil compelled him to use. He was apprehended on a charge of sorcery, and condemned to be burnt, but he saved himself by revealing his secret.

The art soon spread abroad, and presses were set up in several parts of Germany, of which Bamberg, Cologne, and Augsburg are

the most celebrated. In 1469, two of Faustus' workmen were invited by some Doctors of the Sorbonne, to Paris, and about the same period, two Germans began to practise their art at Rome. A press was established at Florence, another at Venice, and these and other Italian presses were so industrious that in the nine years between 1471 and 1480, we are informed that 1297 books were printed south of the Alps. A Greek grammar was printed at Milan in 1476, and a Lexicon four years afterwards. Hitherto when any Greek words occurred in a book, blank spaces were left, and the pen inserted them. In 1480 Hebrew characters appeared, the work of two Jewish Rabbis. South of the Alps, the printers were busy; and in 1473, a gigantic work, being an Encyclopedia, in ten folio volumes, was printed by Mentelin at Strasburg. Presses were set up at Basle, and at Utrecht, Louvain and other places in the Low Countries. Several towns in France issued specimens of typography, chiefly in the Latin language. It has long been a disputed point what was the first work in the French tongue; some connoisseurs supporting the Garden of Devotion, by Mansion of Bruges, whilst others are firm in setting forward the Romance of Count Balduni of Flanders, printed about 1474. Two years after that date, a large volume called the Chronicles of St. Denis, was printed at Paris.

It was about this period that the art was introduced into England by William Caxton, who, after he had served his apprenticeship to a London merchant, went abroad, where he remained some years. Some say he was sent over by Edward IV. to negotiate a treaty with the Duke of Burgundy. Whilst resident at Cologne, he translated into French a work on the history of Troy, by the direction of the Duchess of Burgundy, and printed it. A copy of this book sold at the sale of the Duke of Roxburgh's books a few years ago, for £1060. Not long afterwards he came to England, and set up a press in Westminster under the patronage of the Abbot, and the first book he produced related to the game of chess, and in 1477 he published a translation from a Latin compilation entitled "Dictes and Sayings." Altogether he printed sixty-four works; but the date of his death is not accurately known. None of his books are very important in a literary point of view, but the number of them shows that he had exercised his art with industry. Caxton had a contemporary of the name of Letton, but he produced only eleven works, the majority of which were printed when he was a partner with William Machlimar. Wynhyn de Worde succeeded old Caxton, and from his press issued 408 works between the years 1493 and 1534. Robert Pynson had the title of king's printer given to him, and he printed in thirty-eight years 210 works. A native of Cologne carried the art to Oxford about 1480, but at Cambridge the earliest books are dated 1521. A Breviary published at Edinburgh in 1510, is the first specimen of the art in Scotland. A religious work on the Virgin appeared at Vallencia in 1474, and this was the earliest printed book that Spain produced.

The characters of the early printers are remarkable for their size and rudeness. They were usually Gothic, mingled with imitations of hand-writing. The date and printer's name are frequently wanting, and a regular title-page was not often given. The colon and the full stop were the only points in use at first. The elder Aldus introduced the plan of giving a mark or emblematic vignette; and we find monograms or cyphers containing the printer's initials, or some curious device, in fashion. A bibliographer can tell by a glance who was the printer of any work from his device. Faust and Schoeffer are said to be the first who gave their initials. Caxton had three devices; so had Wynhyn de Worde. John Day, who issued works between 1546 and 1584, had a little wood-cut representing a landscape on which the sun was rising, and a man was rousing a sleeper with the words "Arise, for it is day." In progress of time the pages were numbered, and abbreviations, with which the books of the early printers abounded, were discountenanced. Errors sometimes were very numerous, and it became advisable to accompany printed volumes with a list of errata. A work published in 1561, called the Anatomy of the Mass, has a list of errata extending to fifteen pages, although it is only a thin book of 172 pages; a notice is prefixed to the list, by the corrector, a pious monk, who accuses Satan with being at the bottom of the blunders, and that to ruin the work he had first steeped the manuscript in filthy water, and then befooled the printer's brains and fingers.

The press was at the commencement a very rude machine. The first change in their make was wrought by an ingenious printer of Amsterdam, named Blaew, who had been brought up as a carpenter, but having become acquainted with Tycho Brahe, he turned his attention to the making of astronomical and mathematical instruments, and he published an Atlas in three volumes folio, in the execution of which he engaged all the celebrated geographers of his time. Having discovered many imperfections in the printing-press, he studied to remedy them, and he succeeded in making many improvements. He caused nine to be made after his plan, and named them after the Muses. Presses of his structure soon became general in the Low Countries, from whence, after a bigotted attachment to the clumsy old ones, they were used by the printers here. It was not until the commencement of the present century that any further improvements of consequence were introduced. The Stanhope and the Columbian presses are well known as being the very successful result of efforts to improve the mechanism of printing, and these hand presses have perhaps reached the ultimatum of the excellence of which they are capable. The first of those we have just named, was the invention of Lord Stanhope, assisted by an ingenious machinist, about 1800, and although it has undergone several alterations since that time, the principle of the invention belongs to his Lordship, who declined to take out a patent for it, and the manufacture of presses upon his plan became common. Its superiority consisted in this, that by the adjustment of the screw and lever a single pull was sufficient to take off an impression, but on the old system two separate efforts were required. Not more than 250 impressions however per hour could be worked off with the most improved press; and as the impression was only on one side, it followed that only 125 printed sheets could be executed in that time. In 1814, steam power was first applied to the process of printing, and the machine has now been brought to such perfection that upwards of ten thousand sheets can be printed in an hour, this being the rate at which the *Times* newspaper is printed daily. A full account of the successive improvements, resulting in Applegath's vertical machine, has been given in Vol. I., p. 479.

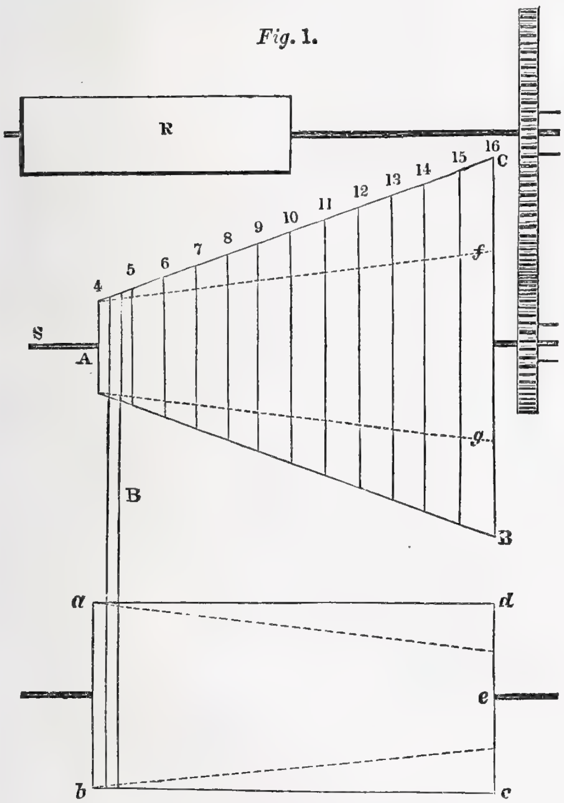
Before we can print, we must have types, and type-founding is generally a separate trade. The different sizes into which the types are cast are termed bodies, and there are nineteen of them. About a hundred pounds weight of type is considered a moderate sized fount. The matrix is of copper, impressed by a steel punch, and it is placed in a steel mould the size of the shank of the type. The mould is then held in the founder's left hand, whilst he pours the molten metal out of a ladle into it with his right. The mould is quickly opened, the type thrown out, and the workman repeats the process. In this way from 400 to 550 types can be cast per hour. Towards the end of the sixteenth century a printer at Leyden first used stereotype printing in producing a quarto edition of the Bible. William Ged, an Edinburgh goldsmith, was the first who used the process in this country, about 1725, and having entered into partnership with two other persons, they obtained a privilege from the University of Cambridge for printing Bibles. Some quarrel unluckily broke out, and one of the partners maliciously injured the works. The Bibles printed after this were

so full of errors that the king prohibited them to carry on their operations further. The mode of forming stereotype plates is this; after the type has been composed and set in form as if it was to be printed from, it is carefully cleaned and then oiled. A cast is then taken from it in plaster of Paris, or in a pulpy preparation of paper, and baked. When hard enough, it is placed in a box or frame, and a quantity of molten metal is poured over the whole. The mould is then removed, and the stereotype plate is produced, from which almost any number of copies can be taken as they are wanted. When a large number of copies are required, and particularly where simultaneous publication at several places is necessary, the stereotype process is generally adopted. The early printers were usually their own publishers; and publishers now-a-days are frequently their own printers, especially when periodical works are in question.

ON CONICAL OR TAPER DRUMS.

Suppose the conical or taper drum, A B C, to taper from 4 to 16 inches, or in the ratio of one to 4, and to be driven from the paralled drum, *a b c d*, and that the strap or belt, B, is made to tra-

Fig. 1.



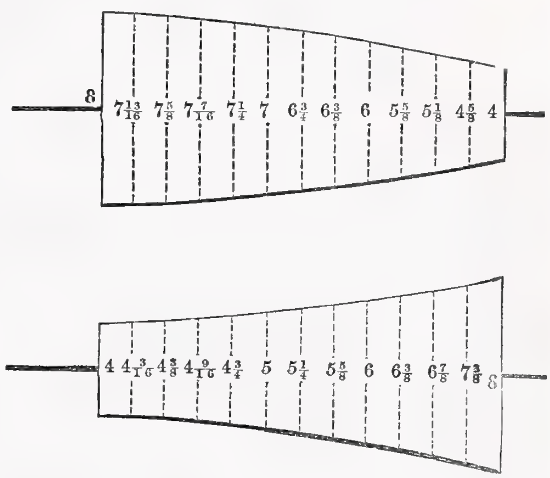
verse uniformly from end to end, in order to diminish the speed of the shaft S, in the same proportion as the diameters of the drum increase. Now, to keep the strap of sufficient uniform tension, it is proposed to turn down both these drums, or substitute them by making two equal cones, tapering in the ratio of $\sqrt{4} = 2$ to 1, *i. e.*, each end to be 8 and 4 inches diameter respectively, as represented by *a b e* and *f g* A. It is found notwithstanding that the speed of the shaft S will be exactly the same at the two extremes in both arrangements, yet when the strap is in the middle, or in other intermediate part, there is a variation in the result, and which is often a source of error in applications of this nature, to various parts of machinery where accuracy is required. For instance, when the strap has traversed half-way on to the middle of the drums, we shall have 8 inches driving 10 inches in the first arrangement; but by the two equal cones, 6 inches will be driving 6 inches diameter, which are greatly at variance, and give different speeds to the shaft S, and therefore not what is sought. So that it is evident that the two cones must not be of a regular taper, but of some other form, which will be found to be concave and convex, as represented by the curved lines in the next figures., and the sum of whose opposite diameters are everywhere the same, *i. e.* $8 + 4 = 12$. And to keep the speed the same as before, they must be to each other in the same ratio as the diameter of the parallel drum and each respective diameter of the cone A, B, C, *i. e.* in the ratio of 8 to 4, 8 to 5, 8 to 6, &c., ... 8 to 16.

The diameters of the driving cone, to correspond to every inch diameter of the driven one, are formed thus:—

$$\left.\begin{array}{l} 8 + 4 : 8 :: 12 : \frac{96}{12} \\ 8 + 5 : 8 :: 12 : \frac{96}{13} \\ 8 + 6 : 8 :: 12 : \frac{96}{14} \\ \quad \&c. \quad \&c. \quad \&c. \\ 8 + 16 : 8 :: 12 : \frac{96}{24} \end{array}\right\}$$

Diameters of the driving cones which being severally subtracted from the sum of both (12) will give those of the driven cone, and which will be found to be as represented in the diagrams subjoined.

Fig. 2.



From these diameters the cones can easily be constructed correctly, the traverse of the strap remaining uniform as before.

If more accuracy is required in setting out the form of the cones, they may be calculated for every half inch diameter, by dividing by 12, $12\frac{1}{2}$, 13, $13\frac{1}{2}$, &c., to 24.

Again, if it be desirable to have the two cones equal and of regular taper, this may be the case, provided the traversing of the strap be made to vary its speed for each shift agreeably to the respective difference of these diameters; for, *as the total difference of the diameters of the two ends, is to the total length of the cone, so is each respective difference to the length moved by the traverse for each variation;* thus,

$$\begin{array}{l} \qquad\quad \text{Length.} \\ 8 - 4 : l :: \frac{96}{12} - \frac{96}{13} : \left(\frac{24}{12} - \frac{24}{13}\right) l = \text{1st shift.} \\ 8 - 4 : l :: \frac{96}{13} - \frac{96}{14} : \left(\frac{24}{13} - \frac{24}{14}\right) l = \text{2d do.} \\ 8 - 4 : l :: \frac{96}{14} - \frac{96}{15} : \left(\frac{24}{14} - \frac{24}{15}\right) l = \text{3d do.} \\ \quad \&c \qquad\qquad \&c. \qquad\qquad \&c. \end{array}$$

Therefore, if the constant number 24 be divided by 12, 13, 14, 15, &c., &c., to 24, and the proceeding quotient subtracted from the preceding one, and these severally multiplied by the total length, we obtain the length or distance moved by the traverse for each variation, from which a rack or scroll can be constructed to work the traverse, and by which the speed of the shaft S will be kept uniformly varied as before.

Suppose it was desired to coil up cloth (of various thickness) at a uniform speed on the roller or beam, R, fig. 1, it is quite evident, that, as the beam becomes increased in diameter, its revolution per minute must be decreased. Now, this can be easily and correctly accomplished by using one taper drum, whose extreme diameters are to each other in the same ratio as

the empty beam is to the full one, the driving drum remaining constant, and the traverse of the strap being governed by the thickness of each coil. But it would be impracticable to effect this by two equal cones, and if such be used, they must be constructed of the concave and convex form as before named, the larger diameter being found by multiplying the smaller by the square root of the ratio required.

MEMOIR ON THE ELASTIC FORCE OF STEAM.

BY M. V. REGNAULT.

The calculation of the labouring force of steam engines requires a knowledge of certain physical laws, which are as yet far from being accurately established. The principal of these laws relate to the following subjects:—

1st. The elastic force of steam at various temperatures.

2nd. The amount of heat that exists in a given weight of steam, *saturated* with heat, under various pressures; or, more exactly, the amount of heat given out by 1 kilogramme of saturated steam under various pressures, when it is converted into the liquid state at 0° cent.

3rd. The specific heat of water at various temperatures.

4th. The density of saturated steam under different temperatures.

4th. The density of saturated steam under different pressures.

In this memoir, I shall confine my attention to the elastic force of steam at various temperatures.

I.—Almost every experiment on the tension of steam at low temperatures, has been performed by means of two barometers placed in the same cistern of mercury; one of the barometers containing a small quantity of water which diffuses itself throughout the barometric vacuum. The difference of the heights of the two barometers exhibits the tension of steam corresponding to the temperatures to which the barometers are exposed at the time of the observation. The most objectionable feature in this mode of determination, consists in the difficulty of exactly determining the temperature corresponding to the observed tension. Experimentalists have, for the most part, contented themselves with placing near the barometers a mercurial thermometer, the indications of which, they considered, gave the real temperatures corresponding to the tensions.

The same process has been employed by various experimenters for temperatures higher than the atmospheric temperatures. In this case, the two barometers were placed in a glass muffle, full of water, the temperature of which is gradually raised. Mr Dalton placed the humid barometer singly in a second glass tube of larger diameter, closed at the base with a cork stopper, through which the barometer tube was passed; the space between the two tubes was filled with water heated to various temperatures. This process is susceptible of little precision, as it is impossible to maintain a fluid column of a certain height, at a uniform temperature without continually agitating it; and, in the experiments of Dalton, there are no means of rendering the temperature stationary for a period sufficiently long to bring the mercurial column to the same temperature as the fluid which surrounds it. I made experiments by this mode, with a view to ascertain how far it could be depended upon for yielding exact results. For temperatures equal or little superior to the surrounding temperature, the results afforded were very exact; but for higher temperatures, the indications became less so. In the latter case, the water so readily subsided into horizontal strata of different temperatures, that, to maintain a uniform temperature, it required to be constantly and rapidly agitated; and when allowed to rest for the purpose of observing the levels of the mercurial columns, the separation into strata commenced, and the observations became uncertain.

Another series of experiments were made by means of an apparatus consisting of two barometers, the one dry and the other wet, similar to what was employed in the experiments just noticed; the two columns, however, were not heated throughout their lengths.

Two barometers, as like each other as possible, 14 millimetres (·55 inch) diameter, are laid side by side on a board, P, figs. 1 and 2, having their lower extremities immersed in the same cistern of mercury, U. These barometers pass through two openings in the bottom of a galvanised sheet-iron chest, V, and are retained there by a packing of caoutchouc; this chest, represented in horizontal section in fig. 3, has a rectangular opening in one side, bordered with an iron frame, F. A sheet of plate glass is fixed against this frame by means of a second frame, E, similar to the first, and fixed to it by means of screws. A thin packing of caoutchouc is interposed between the frame F and the glass, to render the joint water-tight. The cistern, V, stands on an iron stool, T; its capacity is about 2750 cubic inches, or 1·6 cubic feet.

To ascertain what effect the interposition of the glass and water had upon the levels of the mercury in the tubes, as observed by means of a cathetometer, there was traced upon the dry barometer a very fine horizontal line at about the ordinary height of the mercury; and upon the wet barometer a series of divisions in centimetres (·3937 inch). The distances of the mark on the dry barometer from those on the wet one, were then observed, first, without the interposition of the glass, and secondly, with the glass and water both interposed. It was found that the absolute deviation of the rays of light in the second case amounted sometimes to ·0196 inch; but that the relative deviations of the wet marks from the dry mark were always much less, never amounting to more than ·0039 inch. Great care, also, was taken to place the tubes vertically and parallel to the glass.

The cistern, V, is filled with water, maintained in a state of continued agitation by an assistant; a very susceptible mercurial thermometer is immersed in this water, and its indications are observed by means of a small horizontal glass, L. The observer directs the cathetometer to the summit of the meniscus of mercury in the wet barometer; at the instant of making the observation, the agitation is suspended; and immediately after, it is renewed; it is again stopped, and the surface of mercury in the dry thermometer is observed. The water is thus maintained in a continued state of agitation, easily effected as the capacity of the vessel is great.

These observations are made with great precision, at the temperature of the surrounding atmosphere, and may be repeated as often as may be deemed desirable. At higher temperatures, part of the cold water is raised by means of a syphon, and replaced by an equal amount of warm water; and again, for still higher temperatures, a spirit-lamp is applied externally to the bottom of the cistern, V, in more or less proximity to it; thus any desired temperature, within certain limits, may be attained, and, as the water is kept in continual agitation, the temperature remains perfectly stationary, and may be so maintained as long as it is required at any point under 50° cent., or 122° Fahr.

Several observations were made at intervals to test the constancy of the indications, and the same tensions were invariably indicated at the same temperatures.

It will be seen that, according to the arrangement just described, the two columns of mercury are not heated throughout their lengths. But the portions external to the cistern, V, are placed in identical circumstances, and the difference of the heights of the two columns is at the temperature of the bath; this difference, reduced to zero, will give the tension of the steam. It may be questioned, however, whether all the space occupied by the steam in the wet barometer is exactly at the temperature of the bath, seeing that the surface of the mercury may be at a lower temperature on account of its proximity to the colder mercury below it. This latter circumstance might certainly exist, if the level of the mercury had ever sunk too near the bottom of the bath; this, however, never took place in these experiments, the level always standing at several decimetres above. Independently of these considerations, it was made a matter of direct experiment. Two tubes of the same diameter as the barometer tubes, and closed at the under end, were passed through the bottom of the bath, their closed ends reaching to the surface of the mercury in the cistern, U, and their open ends rising

above the level of the water. These tubes were filled with mercury, one of them to the ordinary height of the mercury in the dry barometer tube, the other to the lowest height of that in the wet tube. Observations being made on the levels of

Fig. 1.

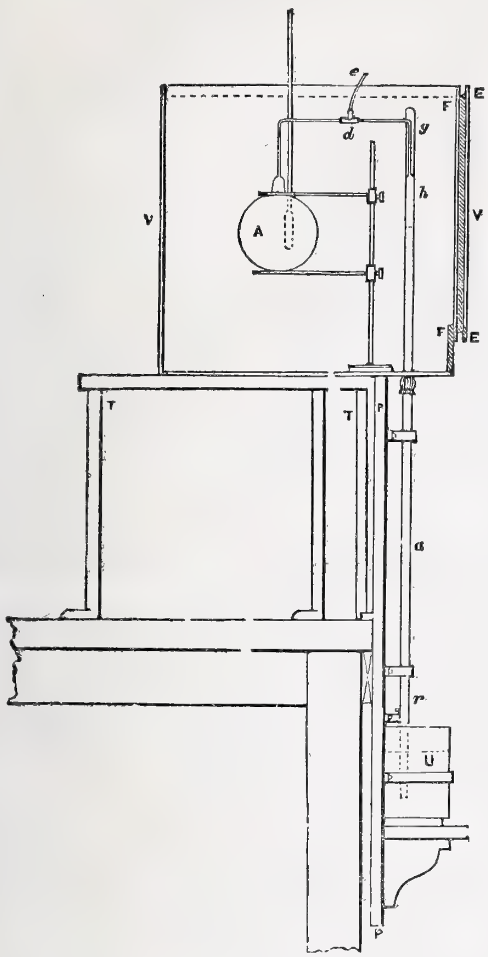


Fig. 2.

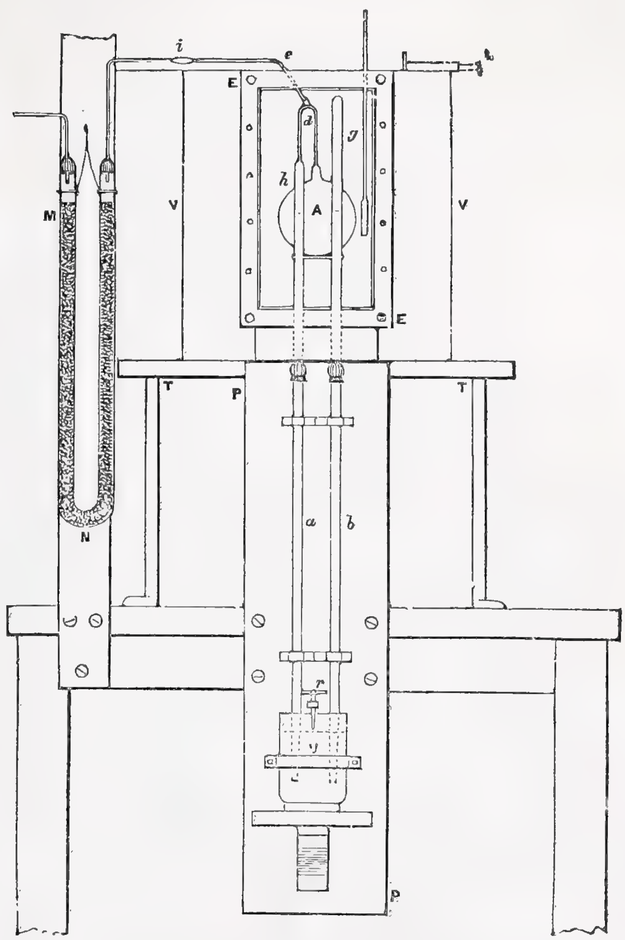
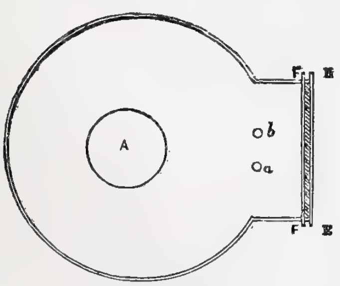


Fig. 3.



the mercury in the two tubes at various temperatures. it was found that the differences of level were, when reduced to zero, always the same, neglecting a trifling disparity which never exceeded ·0027 inch; this was just what had been reasonably anticipated, and it proved the fairness of the indications of the barometers. It was further found, by means of a very sensible thermometer plunged into the tube with the smaller quantity of mercury, and then withdrawn and plunged into the bath, that, in the course of three minutes at least, the mercury always attained the temperature of the bath.

The mercury in the wet tube was always covered with a stratum of water ·12 to ·16 inch deep. This so far depreciated the column of mercury, in virtue of its weight, and that inversely as the specific gravity of mercury, or to the amount of 1-13·5th of the thickness of the water, which was of course to be added to the height of the mercurial column to approximate to the required height.

The thickness of water was determined by taking, with the cathetometer, the least depth between the convex surface of the mercury and the concave surface of the water.

But again, the capillary influence of the water in raising the level has to be deducted from its depreciating influence, to arrive at the true level. The capillary force was determined by direct experiment. To the upper ends of the barometrical tubes employed in the experiments, were soldered glass tubes of small bore, the ends of which were cemented to the ends of a small three-way copper tube. A third glass tube was cemented to the third branch of the copper tube, and was likewise connected to the air-pump. Between one of the barometrical tubes and the copper tube, a bent tube, like U, was cemented, filled with powdered sulphur as a drying medium. The two barometers having been plunged into the same vessel of mercury, the air was several times exhausted and re-admitted, so as effectually to dry the interior of the tube communicating with the sulphur; when the air was for the last time exhausted, the small tube leading to the air-pump was melted and hermetically sealed at a lamp. Having

ascertained that the mercury stood at the same level in the two tubes, a quantity of water was introduced into the tube not in connection directly with the sulphur, about as much as there was during the experiments. The two barometers now assumed their new levels, one of them having a quantity of water additional. It was then found, on examination, that a difference of level of ·0047 inch was due to the capillary action of the water.

[There is here subjoined, in the original memoir, a table of the results obtained by means of the apparatus just described, between the temperatures of 7·52° and 58·62° cent.]

II.—The second series of experiments were made by means of the apparatus represented in figs. 1, 2, 3. A glass globe A, of about 76 cubic inches of capacity, contains a glass globule quite full of recently boiled water. Two small tubes rise from the globe A, and the upper end of the barometrical tube *h*, and meet in a brass three-way joint, *d*, from which another small tube rises and connects the globe and the tube *h* with the air-pump; there being interposed, however, a bed of sulphur in a bent tube M N, about 3 feet in total length, in the passage to the pump. The other barometrical tube, *g*, stands in the same vessel U with the tube *h*, but is otherwise quite distinct from it.

The apparatus being thus arranged, the air in the interior of the globe A and the tube *h* was extracted from forty to fifty times successively, being, after each evacuation, re-admitted slowly through the sulphur-bed M N; the interior of those parts being thus perfectly dried, they were exhausted for the last time, and as perfectly as possible. When the pump was cleaned and in good order, it produced a vacuum often less than ·039 inch. After the last exhaustion, the tube was hermetically closed by the blow-pipe; then the globe A was surrounded by melting ice, and after a short interval, the difference of the heights of the two columns was taken, which would give, of course, the elasticity of the dry air in the globe at 0°. The ice being then removed, the globe was heated by a small chafing dish applied below it, until the globule of water burst by the expansive force of the latter. The globe was then again enveloped in ice, and the difference of heights again observed. This difference diminished by that which is due to the remaining air, gives the tension of steam at 0° cent. This observation was frequently repeated at intervals of 10 minutes, to make certain of the constancy of the indications. For higher temperatures, the experiments were conducted precisely as in the former experiments, the glass plate being fixed in the rectangular-frame, the cistern filled with limpid water, and the same precautions employed in allowing for the deviation of the rays of light through the glass and water. [The results of these experiments are set down, in the original, in several series, comprehending temperatures between 0° and 49°·7 cent.]

In all the experiments, there were means of checking the barometer *g* by comparison with a normal barometer at any instant of the experiments. A screw, pointed at both extremities, was suspended from the board P over the surface of the mercury in the cistern U, and being turned until its lower end touched the surface of the mercury, the level was thus accurately ascertained; then the height of the mercury in the tube, above the upper end of the screw, was taken with the cathetometer, to which the height of the screw being added, the whole height of the column was found. During these trials, the vessel V was, of course, empty, and the glass plate removed. There is another mode of proving the barometer, long ago employed by M. Arago, the addition or abstraction of a quantity of mercury to or from the cistern U, and observing the height of the column above the surface; if the height remain always the same, the vacuum in the upper end of the tube must be perfect.

The same arrangement of apparatus is readily applicable to the determination of the tension of steam at low temperatures; there being substituted for the cistern V, a glass vessel of 1220 cubic inches or ·706 cubic feet of capacity. The tension at 0° was first ascertained, as before, by enveloping the globe in melting ice; then the ice was replaced by a concentrated solution of chloride of calcium, and the temperature gradually lowered by the occasional introduction of fragments of ice, the fluid being maintained in a state of continual agitation. To obtain the greatest degrees of cold, the crystallised chloride mixed with snow in alternate layers, was employed. To maintain the minimum temperature, small quantities of snow were added from time to time. To raise the temperature, a hot solution of the chloride was added, in preference to water, as the strength of the compound was thereby preserved undiminished. [The experiments made in this manner are recorded in three series, extending from 0° to — 32°·84.]

As it was essential that the dessication of the air in the globe should be as perfect as possible, it was done in another way as follows:—The globule of water was enveloped in a short piece of tube attached to the tube *e*; the globe A, and tube *h* were exposed to a heat of 300° or 400° cent., then the exhausting process was commenced and completed more thoroughly than in the foregoing experiments. The tube *e* being then closed by the blow-pipe, the whole was allowed to stand till next day, when the globe was enveloped in ice, and the corresponding elastic force of the enclosed air at 0° was taken. The whole was allowed to stand till next day, when the globe was enveloped in ice, and the corresponding elastic force of the enclosed air at 0° was taken. The globule was then burst by heat applied externally, and the water distilled over into the globe A, still surrounded with the ice. The apparatus was now in working condition, and it yielded for the tension of steam at 0° cent., a value slightly less than what was before obtained. [With the apparatus thus arranged, three series of experiments were made, ranging between 0° and 16°·42.]

Finally, with this apparatus the tension of steam in a perfect vacuum was experimented upon. A quantity of water simply was poured into the globe, and the connections completed as before. Heat being applied and the exhausting pump put in operation, the water was distilled over, under a small pressure; the air was thus thoroughly expelled, and the tube being closed by the blow-pipe, the experiments were conducted as before. [Two series of experiments were made in this manner, from 0° to 58°·38.]

III.—[The third section of the memoir is occupied principally with a description of the apparatus for measuring the tensions of gases in general. It concludes with an account of experiments to ascertain the effect of the vapour of the mercury in the barometers upon the tensions indicated in the experiments described in the foregoing sections. The results can be viewed as only approximative, and were generally as follow:—At 100° cent. the tension of the vapour of mercury is nearly ·02 inch; at 50° cent. it is nearly ·004 inch; under 50° its effect may thus be overlooked, and the author has not thought it necessary to introduce this correction in the tables.]

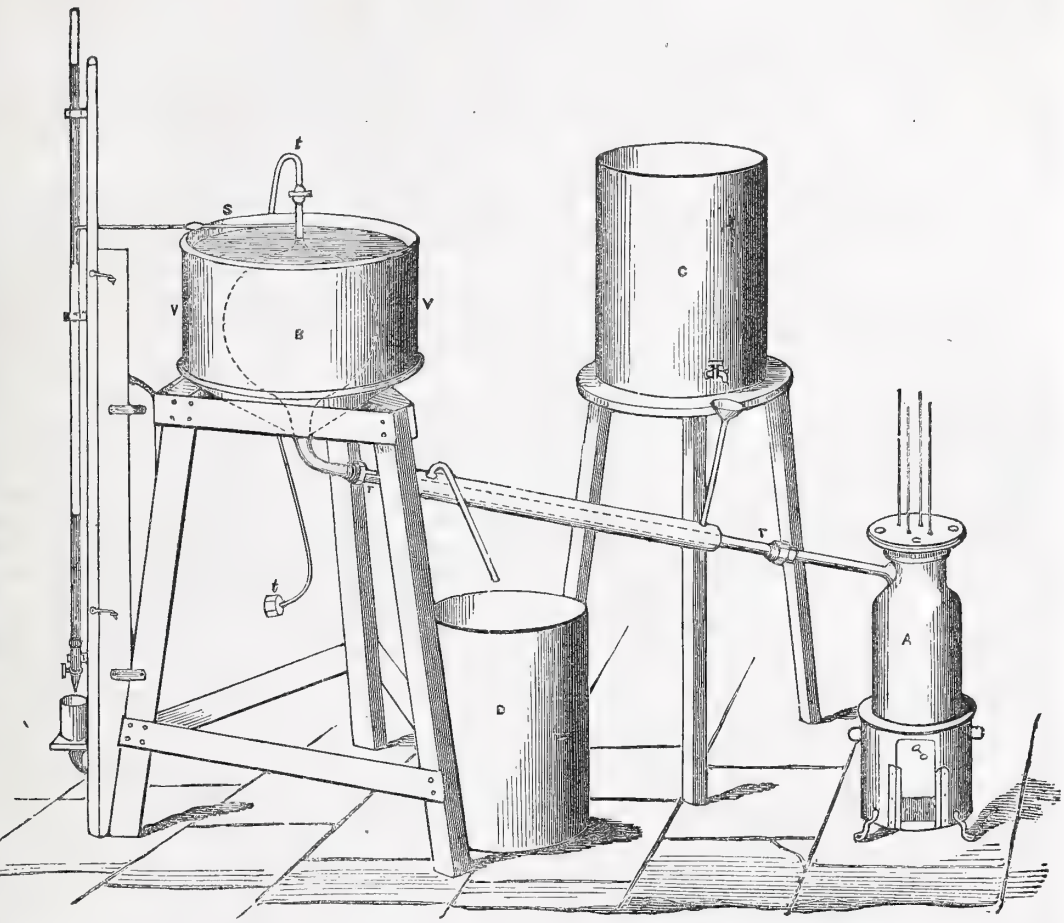
IV.—The methods of experiment described in the foregoing sections are not easily applicable to temperatures higher than 60° or 70° cent.; at higher temperatures, the water so readily subsides into strata of unequal temperatures, that incessant agitation is indispensable to prevent this taking place. Indeed, for temperatures above 100° cent. this mode is quite inefficient.

I have adopted, for high temperatures, a well-known method, often employed, especially by MM. Arago and Dulong; it consists in determining the temperatures at which water boils under given pressures, and may be employed for the highest pressures with great exactness. Under my arrangements, the observations are all made under the same conditions as those in which water boils under the ordinary pressure of the atmosphere, when the boiling point of thermometers is being determined; and the temperatures of the ebullition of water of different pressures may thus be determined with the same precision. With this view, the water is boiled in a vessel freely communicating with another containing air, which may be compressed or dilated at pleasure. An artificial atmosphere is in this way formed, and a temperature of ebullition as perfectly stationary as that of water

boiling under the open atmosphere may be obtained, and for as long a period as may be wished. The apparatus constructed with this view is represented in fig. 4. A copper retort, A, closed in at the top with a flat plate, is placed on a furnace. It is represented in section in fig. 6. The top plate carries four iron tubes, closed at the under ends, and depending into the retort; two of them reach nearly to the bottom of the vessel, the other two reach just to the middle. These tubes, ·275 inch in diameter and ·04 inch in thickness, are inclosed in a very thin muff, *a*, also depending from the

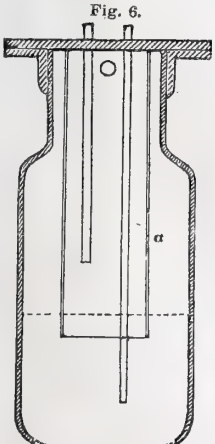
Fig. 5.

Fig. 4.



cover and pierced with small apertures near the upper end. The neck of the retort is screwed to a tube, T, about 39 inches long, enveloped nearly its whole length in a copper muff, through which a constant current of cold water is sent, supplied from a reservoir, C, and running into a receptacle, D. The tube, T, is connected with a copper globe, B, of 1460 cubic inches of capacity, contained in a vessel, V, full of water at the surrounding temperature. The globe is finished at its upper end with a double-branched tube, of which the branch, *s*, is connected to the upper end of barometer, *a*, fig. 1, for pressures less than the atmospheric, or to the tube, *p q*, of the apparatus, fig. 5, as shown in fig. 4 for greater pressures. The other branch is connected by a tube, *t*, to an air-pump for exhausting or condensing the air in the globe, as may be required.

Fig. 6.



The four iron tubes with which the retort, A, is mounted, are filled with mercury to within an inch or two of the upper ends; mercurial thermometers are suspended in them, the bulbs reaching to near the bottom. The bulbs of two thermometers are consequently surrounded by water, and those of the other two by steam.

To measure pressures less than the atmospheric, the apparatus is first exhausted; heat is then applied to the retort, and the steam as it rises and passes along the tube, T, is condensed by the refrigerator and returned to the retort. The pressure under which the steam is now produced is ascertained from the difference of the heights of the barometers, as in the former experiments. A second observer reads off, at the same instant, the indications of the thermometers in the retort. These observations are repeated several times for the same pressure, at intervals of 8 or 10 minutes; thus the most minute variations can be observed. To obtain a higher pressure, the stop-cock on the tube, *t*, is slowly opened to admit as much air as is necessary to produce the increase. Thus the corresponding temperatures and pressures under the atmospheric, may be ascertained by this apparatus.

For pressures higher than the atmospheric, the barometer, fig. 5, is put in connection with the apparatus as represented in fig. 4, and the tube, *t*, connected to the force-pump. The tube, *m n*, is about 13 feet long and ·55 inch diameter. Three

very delicate thermometers are placed in the neighbourhood of the barometrical column at different parts of its height, so as to give its mean temperature. By means of the pump, the pressure in the apparatus is adjusted; it is measured by the height of the barometer, added to the difference of the heights of the mercury in the tubes *mn*, *pq*. To observe these heights with the greatest exactness, two cathetometers are employed, one for each tube, that the heights may be taken simultaneously, at a time when the oscillations of the surface are least. To prove the identity of the divisions of the scales of the cathetometers, I placed them face to face, so that the divisions of the one might be read off through the sight (lunette) of the other; I likewise exchanged their micrometric apparatus, working each with that of the other, and at no point did I observe a discrepancy of more than ·002 inch. In setting the lunettes, also, they required to be susceptible of the utmost accuracy of adjustment. In the cathetometers of M. Gambey, the levels readily indicate inclinations of 1 second; the verniers give immediately ·00078 inch, and it is easy, by them, to appreciate the half of that distance.

As the thermometers are only partially enclosed in the tubes, the upper ends projecting externally, some mode of correcting the indications was necessary. To this end, the mean temperature of the parts of the mercurial columns exterior to the retort, was ascertained by placing a small thermometer at the middle of their heights; and thence the corrections were made. As it was considered doubtful whether this method was sufficiently exact for the purpose, experiments to test it were made with a very exact thermometer, having a range of 0° to 110° cent., and expanded at the upper end into a receptacle into which a portion of the mercury could be transferred. With this thermometer wholly immersed in boiling water, the boiling point was ascertained and marked on it. It was then transferred to one of the tubes in the retort, in which the water boiled at the atmospheric pressure, and the temperature, corrected by means of the small thermometer applied at the middle of the exposed length of the mercurial column, was found to be identical with the boiling point previously marked upon it. Again, to prove that the thermometer indicated exactly the temperature in the retort, as much of the mercury was inverted into the receptacle at the upper end as reduced its level to nearly that of the cover of the retort. Being then replaced in the retort-tube, exposed to a boiling heat, its level was again taken by the cathetometer; it was thence transferred to the original reservoir of boiling water, and the level was found to be exactly the same, proving that the parts of the mercurial columns within the retort were really at the temperature of boiling water. These two experiments proved, 1*st*, that the thermometers in the retort indicate the temperature of the steam; 2*nd*, that the mode of correction above described is exact for the temperature of 100° cent. The greatest correction in this case amounted to 0°·35. I have assumed that the same mode of correction is applicable for lower temperatures than 100°. The thermometers which I employed for pressures under the atmospheric, had 6 to 8 divisions to a degree; consequently, $\frac{1}{60}$th of a degree could easily be read off. The thermometers employed for higher pressures ranged from 0° to 240° cent. The centigrade degree was equal to 2·5 or 3 degrees of their scale. All the instruments connected with these experiments were graduated and proved with the greatest care.

To find the correction for the indications of the thermometers at high pressures, I set the retort in operation to produce steam of a given pressure higher than the atmospheric. Three of the four thermometers were placed in three of the tubes; and the proving thermometer was placed in the fourth tube, such that the level of the mercury rose only a short distance above the retort, requiring therefore no correction. The boiling point of the latter being known, the indications of the other thermometers were reduced on the same principle as in the other experiments, by taking the mean temperature of the exposed portions of the mercurial columns. This process was followed for temperatures of 110, 120, 130, 140 degrees; between these limits of temperature, the discrepancies in the reduction never amounted to more than 0°·2. As this may, in part, be attributed to the inequalities of the thermometer-tubes, I considered the method of correction sufficiently exact, as far as 145°. I designedly commenced the experiments with this apparatus at very low pressures, in order to compare the results thus given, with those obtained by the methods already described. I found a coincidence among them as perfect as could be desired. At low pressures the thermometers plunged in the water showed temperatures considerably greater than those in the steam; at very feeble pressures it amounted to 0°·7. As the pressures and temperatures rose, the differences became less, and ultimately vanished at the atmospheric pressure. [Here follows a table, in the original, of the results obtained, between 43°·55 and 148°·26 cent.]

[The author now enters upon an investigation of the formulæ of interpolation which he considers the most satisfactory. He found that he had to use three formulæ to produce sufficient coincidence between the results deduced from them and his observations: one of these formulæ applied to temperatures below 0° cent.; another to temperatures between 0° and 100° cent.; and the third, to temperatures above 100° cent. He does not regard these formulæ as by any means general, but merely as formulæ of interpolation to fill up the irregularities of the observations. At a future period he proposes to extend his experiments to temperatures much higher than those he had overtaken in the foregoing range of experiments; and to ascertain if it be possible to represent the phenomenon of the relative tension and temperature of steam in its most general aspect, by means of a single formula. In the meantime he has composed the table (page 589) of the tensions of steam at temperatures between —32° and 100° cent., by means of two of his formulæ of interpolation. The temperatures and tensions, given originally in degrees centigrade, and millimetres, are translated into degrees Fahrenheit, and inches, for the convenience of English readers. The fractions of the centigrade degrees are given in ninth parts, so as to avoid the use of common fractions or repeating decimals:—thus, corresponding to 60° Fahr., we have 15° 5 cent., that is, $15\frac{5}{9}$° cent. We attach the annexed table of the temperatures of steam at very high pressures, compiled from experiments made by a committee of the Paris Academy of Sciences, in which MM. Dulong and Arago took a leading part.]

Elasticity in Atmospheres.	Temperatnre in degrees of Fahr.	Elasticity in Atmospheres.	Temperature in degrees of Fahr.
1	212	13	380·66
1½	233·96	14	386·94
2	250·52	15	392·86
2½	263·84	16	398·48
3	275·18	17	403·82
3½	285·08	18	408·92
4	293·72	19	413·78
4½	300·28	20	418·46
5	307·50	21	422·96
5½	314·24	22	427·28
6	320·36	23	431·42
6½	326·26	24	435·56
7	331·70	25	439·34
7½	536·86	30	457·16
8	341·78	35	472·72
9	350·78	40	486·59
10	358 88	45	491·14
11	366·85	50	510·60
12	374·00		

TABLE OF THE TENSIONS OF STEAM AT TEMPERATURES BETWEEN 25·6° AND 212° FAHRENHEIT.

Temperature in degrees of Fahrenheit.	Temperature in degrees of Centigrade.	Tension in Inches of Mercury.	Difference.	Temperature in degrees of Fahrenheit.	Temperature in degrees of Centigrade.	Tension in Inches of Mercury.	Difference.	Temperature in degrees of Fahrenheit.	Temperature in degrees of Centigrade.	Tension in Inches of Mercury.	Difference.	Temperature in degrees of Fahrenheit.	Temperature in degrees of Centigrade.	Tension in Inches of Mercury.	Difference.
—25·6	—32	·0122		34	1 1	·1961	79	94	34 4	1·5972	495	154	67 7	8·3285	2063
25	31 6	·0125	6	35	1 6	·2040	81	95	35	1·6467	519	155	68 3	8·5348	2094
24	31 1	·0131	6	36	2 2	·2121	84	96	35 5	1·6986	526	156	68 8	8·7442	2155
23	30 5	·0137	7	37	2 7	·2205	88	97	36 1	1·7512	543	157	69 4	8·9597	2172
22	30	·0144	7	38	3 3	·2293	89	98	36 6	1·8055	555	158	70	9·1769	2252
21	29 4	·0151	7	39	3 8	·2382	95	99	37 2	1·8610	572	159	70 5	9·4021	2274
20	28 8	·0158	7	40	4 4	·2477	95	100	37 7	1·9182	587	160	71 1	9·6295	2332
19	28 3	·0165	8	41	5	·2572	102	101	38 3	1·9769	599	161	71 6	9·8627	2373
18	27 7	·0173	8	42	5 5	·2674	103	102	38 8	2·0368	621	162	72 2	10·1000	2419
17	27 2	·0181	9	43	6 1	·2777	108	103	39 4	2·0989	627	163	72 7	10·3419	2466
16	26 6	·0190	9	44	6 6	·2885	111	104	40	2·1616	657	164	73 3	10·5885	2520
15	26 1	·0199	9	45	7 2	·2996	114	105	40 5	2·2273	664	165	73 8	10·8405	2583
14	25 5	·0208	10	46	7 7	·3110	118	106	41 1	2·2937	687	166	74 4	11·0988	2601
13	25	·0218	10	47	8 3	·3228	123	107	41 6	2·3624	701	167	75	11·3589	2695
12	24 4	·0228	11	48	8 8	·3351	128	108	42 2	2·4325	720	168	75 5	11·6284	2714
11	23 8	·0239	11	49	9 4	·3479	129	109	42 7	2·5045	740	169	76 1	11·8998	2791
10	23 3	·0250	12	50	10	·3608	137	110	43 3	2·5785	751	170	76 6	12·1789	2831
9	22 7	·0262	13	51	10 5	·3745	139	111	43 8	2·6536	783	171	77 2	12·4620	2889
8	22 2	·0275	13	52	11 1	·3884	146	112	44 4	2·7319	788	172	77 7	12·7509	2951
7	21 6	·0288	14	53	11 6	·4030	149	113	45	2·8107	824	173	78 3	13·0460	2992
6	21 1	·0302	14	54	12 2	·4179	154	114	45 5	2·8931	830	174	78 8	13·3452	3075
5	20 5	·0316	15	55	12 7	·4333	159	115	46 1	2·9761	861	175	79 4	13·6527	3096
4	20	·0331	16	56	13 3	·4492	164	116	46 6	3·0622	877	176	80	13·9623	3203
3	19 4	·0347	17	57	13 8	·4656	170	117	47 2	3·1499	898	177	80 5	14·2826	3225
2	18 8	·0364	18	58	14 4	·4826	174	118	47 7	3·2397	924	178	81 1	14·6051	3313
1	18 3	·0382	18	59	15	·5000	182	119	48 3	3·3321	939	179	81 6	14·9364	3358
0	17 7	·0400	19	60	15 5	·5182	186	120	48 8	3·4260	973	180	82 2	15·2722	3427
+1	17 2	·0419	20	61	16 1	·5368	193	121	49 4	3·5233	980	181	82 7	15·6149	3496
2	16 6	·0439	21	62	16 6	·5561	198	122	50	3·6213	1023	182	83 3	15·9645	3543
3	16 1	·0460	22	63	17 2	·5759	205	123	50 5	3·7236	1033	183	83 8	16·3188	3638
4	15 5	·0482	23	64	17 7	·5964	212	124	51 1	3·8269	1068	184	84 4	16·6826	3662
5	15	·0505	25	65	18 3	·6176	216	125	51 6	3·9337	1086	185	85	17·0488	3785
6	14 4	·0530	26	66	18 8	·6392	226	126	52 2	4·0423	1104	186	85 5	17·4273	3809
7	13 8	·0556	27	67	19 4	·6618	229	127	52 7	4·1527	1152	187	86 1	17·8082	3910
8	13 3	·0583	28	68	20	·6847	241	128	53 3	4·2679	1171	188	86 6	18·1992	3962
9	12 7	·0611	29	69	20 5	·7088	244	129	53 8	4·3840	1201	189	87 2	18·5954	4039
10	12 2	·0640	31	70	21 1	·7332	255	130	54 4	4·5041	1210	190	87 7	18·9993	4118
11	11 6	·0671	33	71	21 6	·7587	260	131	55	4·6251	1261	191	88 3	19·4111	4172
12	11 1	·0704	33	72	22 2	·7847	269	132	55 5	4·7512	1272	192	88 8	19·8283	4280
13	10 5	·0737	36	73	22 7	·8116	278	133	56 1	4·8784	1314	193	89 4	20·2563	4307
14	10	·0773	38	74	23 3	·8394	283	134	56 6	5·0098	1345	194	90	20·6870	4446
15	9 4	·0811	39	75	23 8	·8677	296	135	57 2	5·1433	1368	195	90 5	21·1316	4474
16	8 8	·0850	41	76	24 4	·8973	299	136	57 7	5·2801	1402	196	91 1	21·5790	4589
17	8 3	·0891	43	77	25	·9272	314	137	58 3	5·4203	1425	197	91 6	22·0379	4647
18	7 7	·0934	45	78	25 5	·9586	318	138	58 8	5·5628	1469	198	92 2	22·5026	4737
19	7 2	·0979	48	79	26 1	·9904	332	139	59 4	5·7097	1482	199	92 7	22·9763	4823
20	6 6	·1027	49	80	26 6	1·0236	339	140	60	5·8579	1542	200	93 3	23·4586	4885
21	6 1	·1076	53	81	27 2	1·0575	349	141	60 5	6·0121	1554	201	93 8	23·9471	5008
22	5 5	·1129	54	82	27 7	1·0924	360	142	61 1	6·1675	1603	202	94 4	24·4479	5039
23	5	·1183	58	83	28 3	1·1284	368	143	61 6	6·3278	1629	203	95	24·9518	5196
24	4 4	·1241	59	84	28 8	1·1652	382	144	62 2	6·4907	1666	204	95 5	25·4714	5229
25	3 8	·1300	62	85	29 4	1·2034	387	145	62 7	6·6573	1707	205	96 1	25·9943	5357
26	3 3	·1362	66	86	30	1·2421	405	146	63 3	6·8280	1733	206	96 6	26·5300	5565
27	2 7	·1428	71	87	30 5	1·2826	411	147	63 8	7·0013	1787	207	97 2	27·0865	5582
28	2 2	·1499	73	88	31 1	1·3237	428	148	64 4	7·1800	1800	208	97 7	27·6547	5632
29	1 6	·1572	76	89	31 6	1·3665	435	149	65	7·3600	1871	209	98 3	28·1879	5685
30	1 1	·1648	81	90	32 2	1·4100	449	150	65 5	7·5471	1884	210	98 8	28·7564	5809
31	0 5	·1729	82	91	32 7	1·4549	462	151	66 1	7·7355	1942	211	99 4	29·3373	5839
32	0	·1811	75	92	33 3	1·5011	462	152	66 6	7·9297	1973	212	100	29·9212	
33	+0 5	·1886	75	93	33 8	1·5483	489	153	67 2	8·1270	2015				

[*Note.*—The translation of this table into English necessarily involved a system of interpolation to find the tensions corresponding to the Fahrenheit degrees. This process was easily accomplished by taking proportional parts of the original differences; and it is clear that such a modification of the table in no way diminishes its trustworthiness as a table of reference. The temperatures by the centigrade thermometer are expressed in degrees and nine-parts of degrees, the object of this being to keep clear of vulgar fractions and repeating decimals.]

THE METAL MANUFACTURE.

CHAPTER VI.

BRASS-FOUNDING—CONTINUED.

E concluded our last chapter on this subject (see *ante*, page 491) with a combined view of the brass-founder's shop, exhibiting his various apparatus, with their general position. We now present, in figs. 1, 2, 3, and 4, a series of detailed views of a set of four furnaces of the latest construction drawn to a scale of half an inch to the foot.

Fig. 1 is a front elevation of the furnaces.

Fig. 2 is a ground plan, showing the bars in the first furnace.

Fig. 3 is a front sectional elevation, and

Fig. 4 is an end view, similar to the one given in page 491 Here *a, a,* are the respective furnaces of various gradations

Fig. 1.

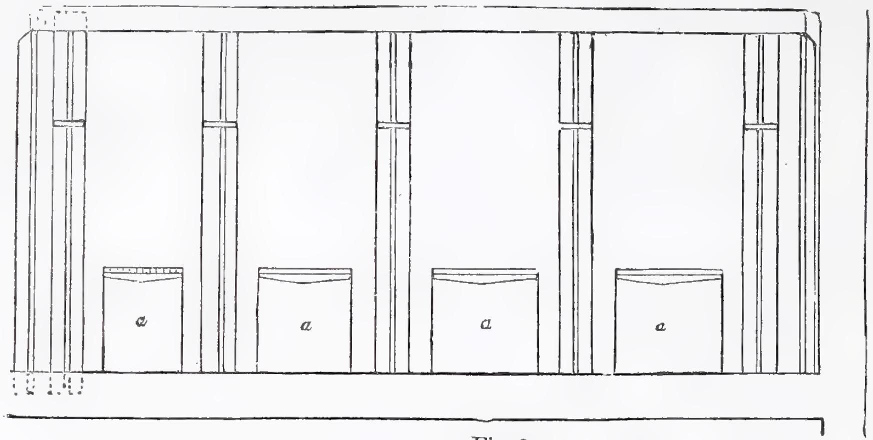
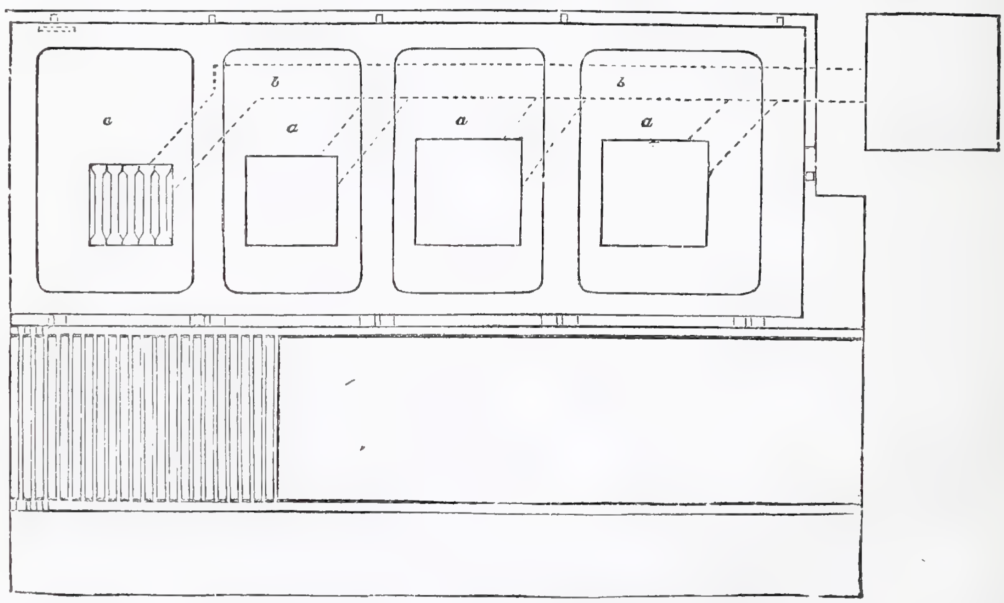


Fig. 2.



of size, to suit circumstances. The arrangement of the flues is shown by the dotted passages, *b, b,* passing along behind the range of fires; the principal dimensions are indicated by the figures, rendering a further detail unnecessary. In the primary arrangement of a brass-furnace, it is necessary to attend to a number of minutiæ, the result of long practice, which, although simple *per se*, would, if neglected, result in serious injury to the founder's operations. In such matters, the mere theoretician who, from the idea of their insignificancy, does not pay the required attention to them, speedily finds himself involved in a long vista of difficulties, fathomable by the experienced practician alone.

The manufacture of crucibles is a branch of the potter's art, requiring great care to insure success, and, until lately, was, at the best, a very uncertain process. The chief requisites in a good crucible are, refractoriness in the strongest heats, capability of withstanding the corrosive effects of any substances that may be ignited in them, and the effects of sudden alternations of temperature. They must also be composed of a material sufficiently solid in its texture to prevent the passage of the fluid metal through its pores. The composition producing pots of the best quality, is formed by pure fire-clay, mixed with finely ground *cement* of old crucibles, to which is added a portion of black-lead or plumbago. The clay is prepared in the same manner as observed in pottery generally; the vessels, after being worked to the proper conical shape, are slowly dried and then baked in a kiln. The composition used in the Royal Foundry of Berlin, is formed of 8 parts in bulk of Stourbridge clay and cement, 5 of coke, and 4 of graphite or plumbago. Crucibles manufactured from this mixture are capable of withstanding the greatest possible heat, in which wrought-iron melts, being

equal to from 150 to 155° Wedgewood; they also bear sudden cooling without cracking. In the Berlin Foundry they have been employed for 23 consecutive meltings of 76 lbs. of iron each, which perhaps is the most complete and trying test that could be adopted.

Another composition is as follows:—8 lbs. Stourbridge clay; 4 lbs. burned clay cement; 2 lbs. coke powder, and 2 lbs. pipe clay; the whole being compressed in moulds whilst in a pasty state.

The Hessian crucibles from Great Almerode and Epterode, resist the action of fluxes, and are tolerably lasting. They are made from a fire-clay, containing a small amount of iron, but no lime; this is incorporated with siliceous sand. These crucibles are rather porous, but they resist the effect of saline and leaden fluxes, and are not liable to crack; yet they melt below the fusing point of bar iron.

The black lead crucibles bear a much higher heat; their composition is two parts of graphite and one of fire-clay; this is mixed into a pasty mass by means of water. The crucibles are baked slightly in the kiln, but are not completely hardened until put into the furnace for use; they are of a smooth surface, and are consequently suitable for gold and the precious metals generally. These crucibles are perhaps the very best yet manufactured, and many of the brass-founders in this country are now adopting them in preference to ordinary clay ones.

Mr Anstey's patent process for the manufacture of crucibles, is as follows:—Two parts of finely ground raw Stourbridge clay, and one part of the hardest gas coke, previously pulverised, and sifted through a sieve of $\frac{1}{8}$th inch mesh, are mixed well together with water. This mixture is moulded on a revolving wooden block, somewhat similar to the process pursued in pot throwing, a guage being used to regulate the thickness of the pot, and a cap of linen placed upon the core previous to the application of the clay, in order to prevent its adhering when removed. The pot is then dried in a gentle heat, and is not thoroughly completed until required for use. It is then warmed before a fire, and laid in

Fig. 3.

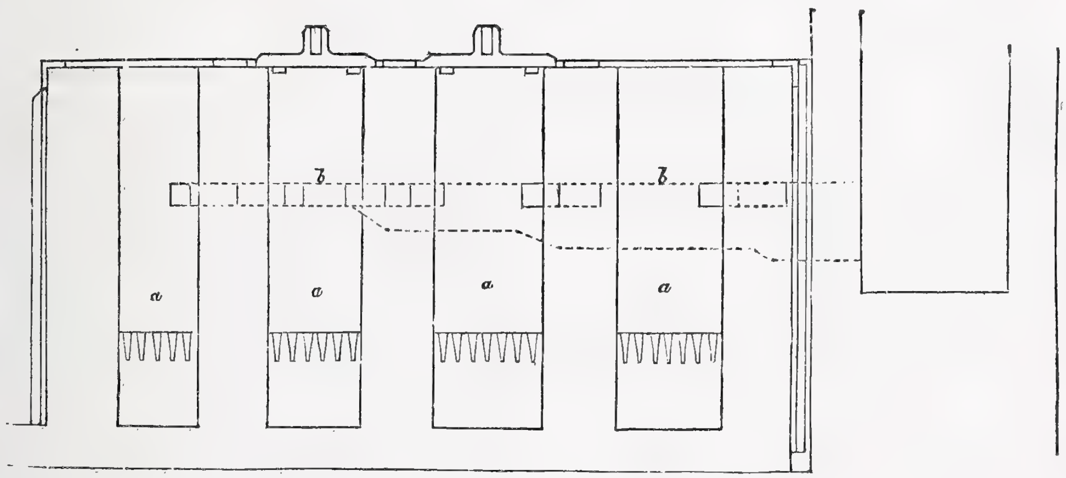
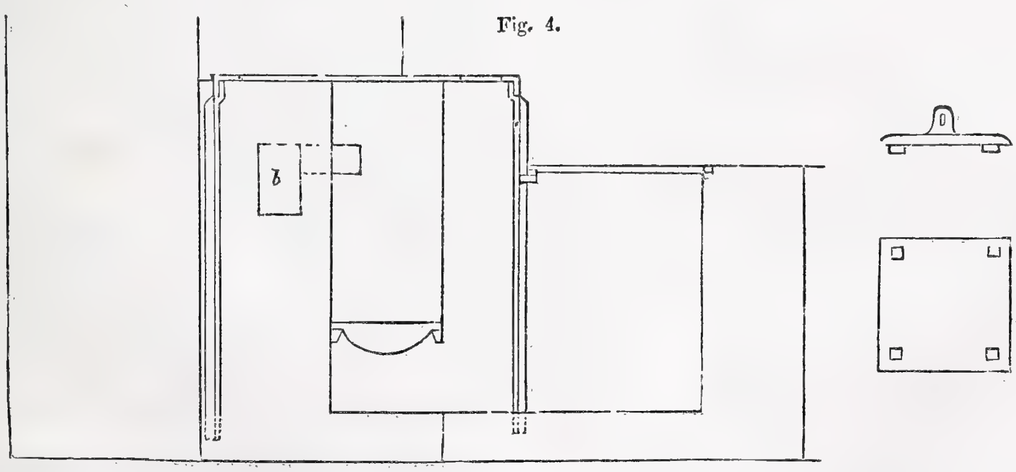


Fig. 4.



the furnace, with the mouth downwards, the heat of the fire having been previously lowered by the application of fresh coke. The furnace is then filled with coke sufficiently high to cover the crucible, when it is gradually brought up to a red heat. When this is the case, it is reversed, and fixed in its proper position in the furnace, without being allowed to cool. The charge of metal is then put into the crucible, and three or four large pieces of coke are placed across the mouth of the pot, the tile or lid is then put down, and the draught of the furnace adjusted to heat the metal quickly. The fusible metals generally, may be mixed in all proportions, but those in which the melting points are pretty near the same are combined in the easiest manner. This is however, a field comparatively unexplored, for, out of the almost numberless compounds which may be readily made, no more than about sixty have been thoroughly examined by experimental chemists, and of this proportionately small number, but few have been practically employed. It is indeed notorious that very slight alterations in the various alloys will often produce effects of the greatest consequence

to the metal worker; thus, the addition of only two per cent. of lead renders brass perfectly manageable in the lathe, although it does not answer for hammering. M. Chaudet has made a number of useful experiments, with the view of detecting the different compositions of alloys by the cupelling furnace. The principle upon which the success of this test depends, is the appearance exhibited by the metal when heated on a cupel.* The purest tin, when heated in this way, fuses, becomes of a greyish black colour, throws off fumes, and exhibits incandescent points on its surface, leaving an oxide, which when withdrawn from the fire, is at first lemon coloured, and when cold, white. Antimony melts, but preserves its brilliancy, fumes, and leaves the vessel lemon coloured while hot, but colourless when cold. Copper melts, and receives a coating of black oxide; occasionally rose coloured spots are detected on the cupel. Zinc burns brilliantly, and forms a cone of oxide, which when hot, is of a green colour, but becomes white when cooled. Bismuth becomes covered with a coat of melted oxide, which is in part sublimated, the remainder entering the pores of the cupel; the colour of the cupel when cold is a fine yellow, tinted occasionally with greenish spots. Lead is very similar in its appearance; the cooled cupel is, however, lemon coloured. In ordinary cases, the specific gravity of the unknown alloy affords a good test for investigating the proportion of the metals. If no chemical condensation or expansion of volume of the metals took place, then a very simple rule would give the required answer.

A neglect of this, has led to very fallacious results: for, supposing two metals of known densities to be amalgamated with each other, it would appear that the arithmetical mean of their respective specific gravities would denote the actual specific gravity of the compound mass.

In order to understand the extent of the chemical change which takes places in many mixtures, we will take iron as one of the most infusible metals, for an example. If iron is alloyed with gold, its refractoriness is almost annihilated, and it becomes very nearly as manageable as its more precious alloy, requiring little more heat to fuse it. Upon this point, Dr Ure is of opinion that there is a strong analogy between this case and the increase of solubility which salts acquire by mixture, as exemplified in the difficulty of crystallizing residuums of saline solutions, or in chemical language, mother waters.

To provide then for the effects of these vast chemical changes, the relative volumes of the metals must be taken into account in determining the density and character of any given alloy. The following simple rule for calculations of the kind, has been furnished by the chemical authority before referred to:—Multiply the sum of the weight into the products of the true specific-gravity numbers, for a numerator; and multiply each specific-gravity number into the weight of the other body, adding the two products together by way of a denominator. The quotient obtained by dividing the former by the latter is the true mean specific gravity of the alloy.

All alloys, without exception, are far more fusible than the superior metal of which they are composed, as the most refractory metals are easily fused when alloyed with one or more of the softer metals. Thus, platinum, which is scarcely fusible at all, readily combines with any of the inferior metals, zinc, arsenic, tin, and some others. Again, several of the easily fusible alloys melt below the boiling point of water, which is less than half the melting heat of tin, their most fusible ingredient.

The melting and mixing of the several metals, is a point which is far from being reduced to anything like a system in many brass founding establishments, and practical men are often at a loss as to the proper means for securing a definite and uniform alloy. As a general rule, it is necessary to melt the less fusible metal first, and to add the more fusible afterwards. Founders generally are of opinion, that if the metal of the first melting is run out into a bar, and then re-melted, a more complete incorporation is obtained. Where a great difference exists in the specific gravity of the component metals, it is necessary to observe certain fixed rules, in order to obtain a perfectly homogeneous mixture; each metal tends to assume its own particular level in the liquid compound, according to its density; therefore, if the casting is of considerable size, and requires a long time to cool, a partial separation will often take place, the lightest rising towards the surface. In the casting of large bells, guns, &c., composed of copper alloys, the lower portion of the casting is apt to contain too much copper, whilst a corresponding excess of tin is found near the upper extremity. To remedy this objection, requires a dexterous manipulation of the liquid metal, previous to casting, so that at the instant of pouring, the compound may be as near homogeneous as possible. The use of the compound termed *temper*, the composition of which is given at page 73, is to assist in the mixing of metals of different qualities. In the composition of pewter, the minute quantity of copper required, would perhaps never combine properly with the tin; but if, instead of adding the two metals in the requisite proportions at first, the copper is first melted alone with two or three times its weight of tin, so as to form *temper*, the latter may be added in the requisite quantity, to the tin or pewter, and a complete combination is effected. In alloys of zinc, this metal is extremely liable to waste, from its oxidizable and volatile nature; to avoid this, a number of schemes have been adopted, with various degrees of success. According to a patent, granted to Mr Emerson in 1781, the following formula, as given in his own words, was adopted:—"I take spelter ingots and melt them down in an iron boiler: I then run the melted spelter through a ladle with holes in it, fixed over a tub of cold water, by which means the spelter is granulated or sholed, and is then fit for making brass on my plan. I then mix about 54 lbs. of copper shot, about 10 lbs. of calcined calamine, ground fine, and about one bushel of ground charcoal together; I then put into a casting pot a handful of the mixture, and upon it I put about 3 lbs. of the sholed spelter; I then fill up the pot with the said mixture of copper shot, calcined calamine, and ground charcoal. In the same manner, I fill eight other pots, so that 54 lbs. of copper shot, 27 lbs. of shoaled spelter, about 10 lbs. of calcined calamine, and about 1 bushel of ground charcoal, make a charge for one furnace, containing 9 pots, for making brass on my plan. My chief reason for using the small quantity of calamine in the process, is more for confining the spelter by its weight, than for any increase arising from it, and I have frequently omitted the calamine in the process. The pots being so filled, are respectively put into the furnace, and about 10 hours completes the process: and from this charge I have on the average, 82 lbs. of pure fine brass, fit for making ingots or casting plates for making brass battery ware, or brass latten; and my brass made as aforesaid, is of a superior quality to any brass made from copper and calamine."

This plan is somewhat roundabout, and has been generally superseded for ordinary purposes, by a much simpler method. The copper is first melted alone, and afterwards the zinc, broken up in pieces, is pushed below the surface of the melted metal, so as to prevent contact with the atmosphere.

Mr. Holtzapffel rendered no little service to the engineer, by his thorough investigation of this subject, having made a number of experiments directly bearing on the point; we here reprint a portion of the detail of the results he obtained, as given in his "Turning and Mechanical Manipulation," vol. I. second edition.

"The zinc was added to the melted copper in various ways; namely, in solid lumps, in thin sheets hammered into balls, poured in when melted in an iron ladle; and all these, both whilst the crucible was in the fire and after its removal from the same. The surface of the copper was in some cases covered with glass or charcoal, and in others uncovered, but all to no purpose; as from one-eighth to one-half the zinc was consumed with most vexatious brilliancy, according to the modes of treatment; and these methods were therefore abandoned as hopeless. I was the more diverted from the above attempts, by the well-known fact, that the greatest

* A species of small cup, composed of bone earth.

loss always occurs in the first mixing of the two metals, and which the founder is in general anxious to avoid: thus, when a very small quantity of zinc is required, as for the so-called copper castings, about 4 oz. of brass are added to every 2 or 3 lbs. of copper; and in ordinary work, a pot of brass, weighing 40 lbs., is made up of 10, 20, or 30 lbs. of old brass, and two-thirds of the remainder of copper; these are first melted a short time before pouring, the one-third of the new metals or the zinc is plunged in, when the temperature of the mass is such that it just avoids sticking to the iron rod with which it is stirred. In mixing the copper and zinc for my experiments on brass, an entirely different course was therefore determined upon, namely, to melt the metals on a much larger scale, and in the usual proportion, that is, 24 lbs. of copper to 12 lbs. of zinc, to learn the first loss of zinc when conducted with ordinary care; then to re-melt a quantity of the alloy over and over again, taking a trial bar every time, in order to ascertain the average loss of zinc in every fusion. From the residue of the original mixture, to make the alloys containing less zinc, by a proportional addition of copper; and those alloys containing more zinc, by a similar addition of zinc. And lastly, to have the whole of the bars assayed, to determine the absolute proportions of copper and zinc contained in all, and from these analyses to select my series of specimens, as nearly in agreement as I could, with the proportions in common use. This method answered every expectation.

"Twenty-four pounds of copper, namely, clean ships bolts, were first melted alone to ascertain the loss sustained by passing through the fire, which was found to be barely $\frac{1}{4}$ oz. on the whole. A similar weight of the same copper was weighed out, and also 12 lbs. of the best Hamburg zinc, in cakes about $\frac{3}{4}$ inch thick, which were broken into pieces.

"The copper was first melted, and when the whole was nearly run down, the coke was removed to expose the top of the pot, which was watched until the boiling of the copper, arising probably from the escape of bubbles of air locked up at the lower part of the semi-fluid mass, ceased, and the copper assumed a bright red, but sluggish appearance; the zinc was then added. Precaution is necessary in introducing the first quantity of zinc, not to set the copper, which is liable to occur if a large quantity of cold metal is thrown in, simply from the abstraction of heat; and it is also necessary to warm the zinc, that it may be perfectly dry, as the least moisture would drive the metal out of the pot with dangerous violence. A small lump of the zinc, therefore, was taken in the tongs, held beside the pot for a few moments, and then put in with the tongs with an action between a stir and a plunge, regardless of the flare, and of the low crackling noise, just as if butter had been thrown in; the zinc was absorbed, and the surface of the pot was clear from its fumes almost immediately. The remainder of the zinc was then directly added, in about eight pieces, one at a time, much in the same manner: but the danger of setting the copper nearly ceases when a small quantity of the spelter is introduced. After every addition, the pot was free from flame in a few moments, a handful of broken glass was then thrown in, the tile replaced, and the whole allowed to stand for about 15 minutes to raise the metal to the proper heat for pouring, which is denoted by the commencement of the blue fumes of the zinc.

"The pot was then taken from the fire, well stirred for one minute, and poured; the weight of the brass yielded was 34 lbs. 12 $\frac{1}{2}$ oz. showing a loss of 11 lb. $3\frac{1}{2}$ oz., or one-tenth of the zinc or the one-thirtieth part of the whole quantity. This experiment was repeated, and the loss was then 1 lb. 3 oz., the difference being only $\frac{1}{2}$ an oz. By analysis, the mean of the two brasses was $31\frac{1}{4}$ per cent; or instead of being 8 oz. to the pound, it was only $7\frac{1}{4}$ oz.

"Twelve pounds of each of these experimental mixtures were remelted six times, a bar weighing about one pound and a half being taken every time; the two series of trials were conducted in different founderies, by different men, and quite in the ordinary course of work; but the loss per-cent. of zinc was in the six experiments exactly alike in each series, that is, each bar, after the sixth melting, contained $22\frac{1}{2}$ per cent. or $4\frac{5}{8}$ oz. to the pound of copper. The second fusion in each case sustained the greatest loss, (say nearly two-fold); and in the others, taking all the accidental circumstances into account, the loss might be pronounced nearly alike in every fusion.

"In making the alloys with more zinc; the calculated weight of the first alloys was melted, and the amount of zinc was warmed and plunged in with the tongs, whilst the pot was in the fire, the whole was stirred and quickly poured: the losses in weight were rather large, but this is common when the zinc is in great quantity. To make the alloys containing less zinc than the alloy, the calculated weight of copper was first made red-hot and the respective portion of the brass alloy was then put in the pot, by which means the two ran down nearly together: it being found that the copper if entirely melted before the brass was added, incurred a risk of being set at the bottom of the pot, and remelting the mass, wasted the zinc. These alloys came out much nearer to their intended weights.

"In making the tin and copper alloys, very little difficulty was experienced. The copper was put into the pot together with a little charcoal, which was added to assist the fusion, and also to cause the alloy to run clean out; as in pouring gun-metal a small quantity is usually left on the lip of the crucible, which would have been an interference in these experiments. When the copper had ceased boiling, and was at a bright red heat, it was taken from the fire, and the tin, previously melted in a ladle, was thrown in; every mixture was well stirred and poured immediately.

"In the fourteen alloys thus formed, each weighing about a pound and a half, namely, $\frac{1}{2}$, 1, $1\frac{1}{2}$, &c., up to 8 oz. of tin to the copper, (missing $6\frac{1}{2}$ and $7\frac{1}{2}$,) no material loss was sustained in nine instances, and in the other five it never exceeded $\frac{1}{8}$ oz. and that quantity was probably lost rather in fragments than by oxidation.

"Alloys of 2, 4, 6, and 8 ounces of lead to the pound of copper were made under exactly the same circumstances as the last."

BRASS-MOULDING

Having thus, in the course of the present chapter, explained the arrangement of the furnaces employed in brass-founding, having stated the best processes for the manufacture of crucibles, and discussed the *rationale* of the mixture and proportion of the metals used in alloys of copper, the matter leads us to the further consideration of casting them. Brass moulding is carried on by means of two distinct kinds of moulds, namely, earthen or sand, and metal moulds; we shall now enter upon the investigation of the former of the two. The formation of earthen moulds is by no means so simple an affair as it would at first sight appear to be, as it requires long practical experience to overcome the disadvantages attendant upon the material used. The moulds must be sufficiently strong to withstand the action of the fluid metal perfectly, and at the same time must be so far pervious to air as to permit of the egress of the gases formed by the action of the metal on the sand. If the material were perfectly air-tight, then damage would often ensue from the pressure arising from the rapidity of the generation of the gases, which would spoil the effect of the casting, and probably do serious injury to the operator. If the gases are locked up within the mould, the general result is, what the moulders term, a *blown* casting, that is, its surface becomes filled with bubbles of air, rendering its texture porous and weak, besides injuring its appearance.

Plaster of Paris is often used for a number of the more fusible metals—this material, however, will not answer for the more refractory ones, as the heat causes it to crumble away, and lose its shape. Sand, mixed with clay or loam, possesses advantages not to be found in gypsum, and is consequently used in place of it for brass and other alloys. In our previous papers on Iron Founding, we have entered into the subject of pattern making, and the general details connected therewith, so that it is unnecessary to say much

more on that point, as the observations there given, will apply equally well to our present subject. In the formation of brass moulds, old damp sand is principally used, in preference to the fresh material, being much less adhesive, and allowing the patterns to leave the moulds easier and cleaner.

Meal dust, or flour, is used for facing the moulds of small articles, but for larger works, powdered chalk, wood ashes, &c., are used, as being more economical. If particularly fine work is required, a facing of charcoal or rottenstone, is applied. Another plan for giving a fine surface, is to dry the moulds over a slow fire of cork shavings, or other carbonaceous substance, which deposits a fine thin coating of carbon. As regards the proportions of sand and loam used in the formation of the moulds, it is to be remarked that the greater the quantity of the former material, the more easily will the gases escape, and the less likelihood is there of a failure of the casting; on the other hand, if the latter substance predominates, the impression of the pattern will be better; but a far greater liability of injury to the casting will be incurred from the impermeable nature of the moulding material.

For some works, where easily fusible metal is used, metallic moulds are adopted. Thus, where great quantities of one particular species of casting are required, the metallic mould is cheaper, easier of management, and possesses the advantage of producing any number of exactly similar copies. The simplest example which we can adduce, is the casting of bullets; these are cast in moulds constructed like scissors or pliers, the jaws or nipping portions being each hollowed out hemispherically, so that when closed, a complete hollow sphere is formed, having a small aperture leading into the centre of the divison line, by which the molten lead is poured in. Pewter pots, inkstands, printing types, and various other articles composed of the easily fusible metals, or their compounds, are moulded on the same principle. The pewterer generally uses brass moulds; they are heated previous to pouring in the metal. In order to cause the casting to leave the mould easier, as well as to give a finer face to the article, the mould is brushed thinly over with red ochre and white of egg. In some cases a thin film of oil is used instead. Many of the moulds for this purpose are extremely complex, and being made in several pieces, they require great care in fitting. With these peculiar cases, we have at present little to do, and shall conclude our paper with a few observations on the method of filling the moulds. The experienced founder finds that the proper time for pouring the metal, is indicated by the wasting of the zinc, which gives off a lambent flame from the surface of the melted metal. The moment this is observed, the crucible is to be removed from the fire, in order to avoid incurring a great waste of this volatile substance. Previous to raising the crucible, the pieces of coke are lifted from the surface; a pair of tongs having a wide clasp, are lowered down to grasp it, and carry it to the skimming place, where the rest of the coke, dross, &c., is removed by a skimming rod—the metal is then immediately poured. The best temperature for pouring, is that at which it will take the sharpest impression, and yet cool quickly. If the metal is very hot, and remains long in contact with the mould, what is called sand-burning takes place, and the face of the casting is injured. The founder then must rely on his own judgment, as to what is the lowest heat at which good sharp impressions will be produced; as a rule, the smallest and thinnest castings must be cast the first, in a pouring, as the metal cools quickest in such cases, while the reverse holds good with regard to larger ones.

Complex objects, when inflammable, are occasionally moulded in brass, and some other of the fusible metals, by an extremely ingenious process, rendering what would otherwise be a difficult problem, a comparatively easy matter. The mould, which it must be understood, is to be composed of some inflammable material, is to be placed in the sand flask, and the moulding sand is thrown in gradually until the box is filled up—when dry, the whole is placed in an oven, sufficiently hot to reduce the mould to ashes, which are easily removed from their hollow, when the metal may be poured in. In this way, small animals, birds, or vegetables may be cast with the greatest facility. The animal is to be fixed in the empty moulding box, being held in the exact position required, by suitable wires or strings, which may be burnt or removed previous to pouring in the metal. Another mode, which appears to be founded on the same principle, answers perfectly, when the original model is moulded in wax. This model is placed in the moulding-box in the manner detailed in the last process, having an additional piece of wax attached to represent the runner for the metal. The composition here used for moulding, is similar to that employed in forming the cores of busts, &c., namely, two parts brickdust to one of Plaster of Paris; this is mixed with water and poured in, so as to surround the model well. The whole is then slowly dried, and when the mould is sufficiently hardened to withstand the effects of the molten wax, it is warmed, in order to liquify and pour it out. When clear of the wax, the mould is dried, and buried in sand, in order to sustain it against the action of the fluid metal.

If our limits permitted, we might mention the details of numerous other works in the founding of brass; we must for the present content ourselves with a brief examination of one or two cases, which come more or less within the province of the engineer. One of these is the founding of bells, a subject of considerable interest, as works of this kind are often of very considerable magnitude, and demand the skilful attention of the engineer. Large bells are usually cast in loam moulds, being *swept* up, according to the founder's phraseology, by means of wooden or metal patterns, whose contour is an exact representation of the inner and outer surfaces of the intended bell. Sometimes, indeed, the whole exterior of the bell is moulded in wax, which serves as a model to form the impression in the sand, the wax being melted out, previous to pouring in the metal. This plan is rarely pursued, and is only feasible when the casting is small. The inscriptions, ornamental scrolls, &c. usually found on bells, are put on the clay mould separately, being moulded in wax or clay, and stuck on while soft. The same plan is pursued with regard to the ears or supporting lugs, by which the bell is hung. Brass guns are another important branch of this manufacture. They are moulded in a manner quite distinct from any other work of the nature. The exterior surface of the gun is produced by wrapping gaskin or soft rope round a tapered rod, of a length slightly greater than that of the gun. Upon this foundation of rope, the moulding loam is then applied, the surface being turned to the exact shape and proportions of the gun.

A long fire is used by the founder in this process, in order to dry the mould as he proceeds in its manufacture. When perfectly dry, the surface of the mould is black washed over, and again covered with loam, to a depth of two or three inches. This exterior coat of loam, is secured and strengthened by a number of iron bands, and the whole is then well dried. The primary mould is now completely withdrawn from the outer shell, the formation of which renders it an easy matter, as the timber rod leaves the rope with great facility, when the latter may be withdrawn, and the clay covering picked out afterwards. The trunnions of the gun are formed separately, and attached to the shell in the ordinary way. When finished, the moulds are sunk perpendicularly in a sand-pit near a reverberatory furnace, a vertical runner being made, leading to each mould, which it enters near the bottom. A suitable channel communicates with the furnace containing the brass intended for the guns. The metal being introduced at the bottom of the mould, no air can possibly be detained by its entrance, as each mould is full open to the atmosphere at the top. Figure casting is another branch of our subject, and one which, from its general complexity, ranks as the greatest effort of the founder.

As an example of this process, we shall take the moulding of thin ornaments in relief. The ornament, whatever it may be, a monumental bas-relief, for instance, is first modelled in relief in clay or wax, upon a flat surface. A sand flask is then placed upon the board, over the model, and well rammed

with sand, which thus takes the impress of the model on its lower surface. A second flask is now laid on the sunken impression, and also filled with sand, in order to take the relief impression from it; this is generally termed the *back mould.* The thickness of the intended cast is then determined by placing an edging of clay round the lower flask, upon which edging the upper one rests, thus keeping the two surfaces at the precise distance from each other that it is intended the thickness of the casting shall be. In this process, the metal is economised to the greatest possible extent, as the interior surface or back of the casting is an exact representation of the relief of the subject, and the whole is thus made as thin in every part as the strength of the metal permits. Several modifications of the process just described are also made use of, to suit the particular circumstances of the case. What we have said is, however, a detail of the principle pursued in all matters of a similar nature.

Our object in penning these brief chapters has been with the intention of offering a few hints as to the most judicious plan of mixing and melting the metals, rather than the production of a complete code of instructions on the founding art. Our former chapters on Iron-founding will, we presume, be found to contain all necessary information on moulding. It is therefore not necessary for us to repeat what we have there said, which will apply equally well to the subject just discussed, as to the matter for which it was written.

BLEACHING.

CHAPTER II.

THE MECHANICAL OPERATIONS REQUIRED IN BLEACHING—DECOLOURING PROCESS.

After each scouring and each acidulous bath, the pieces are cleaned or rinsed, that is to say, they are cleared by washing in water, by certain mechanical means, from the soluble and insoluble matters they may contain; this operation is not as easy as might at first be supposed. The textile fabric, in fact, in common with all porous bodies, has the property of retaining foreign matters in its pores, or the interstices of the threads. It is therefore indispensable, in order to extract these matters, to compress or squeeze these pores repeatedly, and the water entering them, on the removal of the pressure, gradually carries off all soluble matters which it encounters. As to the insoluble matters, they are caused to disappear by means of the friction between the pieces, aided by the mechanical action of the water. Water is consequently an agent which is indispensable in cleansing and rinsing fabrics. Apparatus of various forms are employed in this operation. Some produce the same effect as washer-women do by beating the clothes they operate upon, but by mechanical means; others consist of cylinders, between which the goods are passed and forcibly compressed; in some, again, the necessary effect is produced by the regular falling or dashing of the goods themselves, whilst in others the water is impelled against the goods with more or less force.

It is not very long since the process of washing the goods was carried on in the following manner in some printworks. The goods were laid upon a platform, and a number of workmen beat them vigorously with bats or flails, whilst other workmen turned them over, and dashed them with a plentiful supply of water. This method is no longer in use, except where manual labour is very cheap. The results it gives are satisfactory when care is taken; but though in summer it is conveniently practicable, in winter it is the contrary, particularly in very cold weather.

Several ingenious machines have been invented as mechanical substitutes for the "hand-beating." One which has long been employed in calico-printing works, and is still to be met with in some of them, is termed a *fuller*, and consists of the following principal parts:—

1. A wooden shaft fitted with cams.
2. A fuller or beater oscillating on a centre.
3. Oaken vessels, in which are placed the goods to be fulled.
4. A leaden pipe running along a cross beam, and communicating with a reservoir of water, which it distributes into the several fulling vessels or buckets, the supply to each being regulated by a stop-cock upon a branch pipe.

The pieces are put in bundles into the buckets, the stop-cocks are opened, and the shaft is set in motion, causing the cams to raise the fuller by its head. The fuller falls by its own weight, and fulls the goods, turning them over and over in a direction opposite to that of the shaft, this motion being due to the hollowed out form of the bucket and the shape of the teeth of the fuller.

The *tumbler*, or *Rouennaise*, as it is called, having been adopted first at Rouen, acts partly in the same manner as the preceding machine, and partly like a pair of squeezing rollers. This machine renders great services to the manufacturer who knows how to use it, and does not apply it to cleanse the finer and more delicate descriptions of goods. Two wooden rollers are the essential part of the machine. The lower one is fluted, and turns upon a fixed axis; the upper is perfectly cylindrical. The curve of its surface coincides with that of the concave flutings of the lower roller, whilst the upper cylinder is continually rising and falling, owing to the action of the flutings, and its end spindles slide in vertical grooves in the wooden framing.

This machine is placed over a running stream, or a large tank, the water of which is constantly being renewed. Below the lower cylinder is a cross bar, furnished with pins standing out laterally to guide the cloth, which passes in a spiral direction between the two rollers. Entirely below the surface of the water is a small tension roller. In proceeding to make use of this machine, a packthread is passed round the tension roller below the water, brought up, and entered in between the rollers at one point. It is then again passed round the tension roller, brought up, and entered in at another point, and so on to the other end of the roller, care being taken to pass the thread once only between each couple of guide pins. The pieces of goods to be washed are united in a single length, and attached to the packthread; after which, the lower cylinder is set in motion, and the cloth is drawn through by the packthread. The motion is continued until all the cloth to be operated upon shall have passed, a packthread being attached to the hindmost piece to serve for a succeeding batch. The goods must finally emerge from the water against the current, to insure their being ultimately in contact with fresh and pure water. Whilst the cloth is winding about the lower roller, and in and out of the water, the upper one is continually being raised by the ridges of the flutings, and as continually falling again into their concavities, their weight producing a considerable pressure, by which the impurities are squeezed out of the interstices of the cloth.

Although at first this machine was only employed in washing strong fabrics, there were nevertheless many accidents occurring, the cloth being cut by the ridges of the flutings. With a view of preventing such accidents, and of rendering this valuable machine capable of treating the finer qualities of goods, a plain roller has been substituted for the lower fluted one. By increasing the pressure of the upper roller, either by making it of larger diameter, or, what is better, exerting pressure upon its spindles, as good a result is obtained as from the shocks in the other machine, caused by the rising and falling of the upper roller over the flutings of the lower one. In fact, the machine thus modified operates so well, that, at its regular rate of working, which is such as to deliver 100 yards of cloth per minute, the water expressed by the last of the three pairs of rollers from the cloth is perfectly clear, and contains in solution no foreign matter whatever.

A machine still more advantageous, though not without some resemblance to the preceding one, is employed in many of the Lancashire works, and also in a bleaching establishment at Alsace, on the Continent. The reader must imagine, on the one hand, a large tank, divided into six or eight compart-

ments, or a series of six or eight separate tanks, each being of such a height that the water overflows from the first into the second, from the second into the third, and so on throughout; in a word, these compartments filled with water, and discharging from one into the other, resemble so many cascades or falls of water. A long line of piece goods is caused, by suitable mechanism, to traverse these tanks, passing repeatedly in and out of them, and in the opposite direction to that of the current of water, commencing with the lowest, and finally being delivered at the highest. In passing from one compartment to another, the cloth is squeezed between a pair of rollers, and it will be easily seen that it will have fewer and fewer impurities to part with as it proceeds, until it finally emerges perfectly cleansed. This apparatus has the advantage of giving the means of cleansing a large quantity of cloth very rapidly, and with a very little water; but the tractive force requires to be so powerful, that the goods are considerably lengthened by the process, as much even as four per cent.

The last machine which we shall mention is constructed upon principles quite different to the preceding, and has long been known in England as the dash-wheel. It is of the greatest utility, more particularly for cleansing muslins and fine stuffs, which are always more or less damaged by other systems of beating. The machine consists of a large drum, divided into four compartments by perforated diaphragms, and into each compartment there is an opening by which the goods to be operated upon are introduced and withdrawn. As soon as the wheel, which is fixed upon a shaft, is set in motion by a prime mover of any description, the goods, saturated with water after being elevated to the top, fall back of their own weight upon the dividing partition, and they are washed and beaten at the same time, for a stream of water brought by a pipe flows into the interior through the openings, and keeps the goods constantly saturated. Twelve or fifteen minutes are quite sufficient for washing one charge of goods, which are introduced into the compartments by two and two, and it is very rare that the goods so treated turn out torn or injured, as they, as it were, beat themselves.

The result of an operation of this nature depends a great deal upon the velocity given to the machine; for if the motion is too slow, the pieces, instead of falling, will slide down the sides of the compartments in such a manner as to receive neither shock nor pressure. If, on the contrary, the speed is too great, the centrifugal force will overcome the effect of the weight of the goods, and the latter will remain in contact with the circumference of the drum throughout the revolution. In order to work well, the wheel should make twenty or twenty-five revolutions per minute, and the fall of the goods should be repeated regularly in less than two seconds, so as to sound like a pulsation.

In some works the goods are cleansed by passing them between a couple of pipes, pierced with a number of small holes like the rose of a watering can, whence spout out so many jets of water. The direction of these jets is such that the goods pass between the pipes in a vertical direction, and the sheets of water strike obliquely on both sides of the cloth in a direction opposite to that of its motion. These pipes are in communication with a reservoir more or less raised above them, so that the water may be ejected against the cloth with as much force as possible.

Now that we have passed in review the different machines for washing and cleansing the fabric, after each operation for reducing the fatty matters, we must say two or three words on their several advantages and defects. When the fabrics to be bleached are of some strength, and besides are not destined to that description of printing wherein colours are used which cause them to shrink, those machines should be employed which produce their maximum effect in the shortest time, and with the least expenditure of power. Taking these three points into consideration, the *Rouennaise* presents the greatest advantages; but if the manufacturer has but a small stream of water at his disposal, he must give the preference to that machine consisting of a series of tanks, which we have mentioned as employed in many of the Lancashire works, and also in a bleaching establishment at Alsace. As to such goods as require extra care, they should be submitted either to the dashwheel or to the action of the rose jets.

If the fabric, without reference to its strength, is intended to be printed with *shrinking colours*, it will be necessary to select a washing machine, which will not render them liable to alter their dimensions in the subsequent processes; otherwise the very greatest care will be required in printing such goods; they will always shrink one way or the other, and thus render it almost impossible to keep perfect register with the various colours. With this to consider, the fuller and the dashwheel will be of the greatest service—the first for coarse goods, the second for light fine goods, for both these machines act upon the goods equally in every direction.

SECOND PHASE OF BLEACHING—DECOLOURATION, PROPERLY SO CALLED.

After having been submitted to the operations of the first stage, the cotton fabrics no longer consist of anything but vegetable fibre and colouring matter. To remove this colouring ingredient, the goods are submitted to agents, which, whilst they modify and change their constitution, do not sensibly injure the cloth. Of these agents, that most anciently employed is the atmosphere. Who does not know, that a piece of cloth exposed alternately to the action of the air and of lies eventually becomes bleached? The oxygen of the air forms an oxide with the colouring matter, modifies it, and renders it partially soluble in water, in alkalies, and in acids; but in order that this effect may be produced, the assistance of the solar rays is necessary, and, above all, a certain quantity of aqueous vapor, for it would be useless to expose a dry fabric in a vessel filled with dry air, if it is wished to remove the colouring matter; whilst, on the other hand, we might expose a fabric in a humid atmosphere in the dark a long time without sensibly affecting the colour. The concurrence of these three agents being consequently necessary, we must study the part performed by each.

It is not difficult to conceive that of the oxygen, when we only look to the result of its action, because there can be no doubt that, in the case under consideration, it only combines with the colouring matter to form an oxide, changing its properties, and liberating a certain quantity of hydrogen; but it is not so easy to explain how this gas brings about such decomposition of the colouring matter. In fact, if it acts directly upon the hydrogen, what need of the concurrence of water? Does this liquid only play an indirect part, that of aiding the chemical action, or does it act directly, becoming condensed in the pores of the fabric? Does the water, by dissolving a certain quantity of oxygen, put this gas in conditions more favourable for acting upon the colouring matter, or does it favour the momentary formation of oxygenated water, one of the most powerful decolouring agents, the production of which would then be due to the contractile force of the fabric?

As to the luminous rays, they evidently serve to set up the chemical action, which takes place, according to the part assumed for the oxygen, either between this last and the colouring matter, which would thus be directly decomposed, or between the oxygen and the water to form oxygenated water, and then produce the same effect.

These remarks will be sufficient to render intelligible the operation of bleaching in the open air; the principles alluded to being, moreover, too well known to require repetition here.

When the goods have been scoured, they are exposed in the meadows for three, four, and five days to the action of the solar rays. If the atmosphere is clear and the temperature high, and if there are heavy dews at night, or if the meadow is irrigated, or the climate humid, the decolouration goes on rapidly; whilst the contrary is always the case, when one or other of these conditions is wanting. When it is the physical agent which fails, the delay must be put up with; when moisture is wanted, the goods must be wetted. In large bleachworks, it is usual to cut narrow gutters in the meadows, which are filled with water, and thus afford a means of sprinkling the goods in the sun. When, by this first exposure upon the grass, a part of the colouring matter has been acted upon, the goods are passed through a new lie, to lay bare another surface of this colouring

matter; the goods are then again exposed in the meadows, and these operations are repeated alternately until the desired pure whiteness is attained. Finally, to give the goods a perfect and standing white, they are *soured*, or passed through dilute sulphuric acid, of which we shall speak further on, when treating of bleaching by chlorine. The ancients perfectly understood that the acidulous application was required to complete the process of bleaching, for they passed through sour milk—which, as is well known, contains a considerable quantity of lactic acid—all the goods bleached by exposure to the open air.

The following details will give an idea of the time required for, and the expenses incurred in, this system of bleaching.

Having washed out the gum in tepid water, at two operations, from the goods to be bleached; and having scoured them, by treating them with a hot bath of soft soap, the effect of which will evidently be to carry off the greater part of the fatty and resinous matters adhering to the vegetable fibre; they are made to undergo—

1. A first scouring, lasting four hours, after which the goods are washed with very great care.
2. An exposure in the meadows during three or four days, according to the weather.
3. A second scouring, followed by a second thorough washing.
4. A second exposure in the meadows, for four or five days.
5. A third scouring, lasting four hours, and always followed by a washing.
6. A third exposure in the meadows, for four or five days.
7. Finally, a treatment with an acidulous solution.

According to this, if the weather is favourable, not less than twelve to fifteen days will be required for the exposure in the meadows, in order to effect the complete decomposition of the colouring matter. When, on the contrary, the weather is bad, the desired effect is never produced under four or five weeks' time. Besides, that the manufacturer will thus lose much time, the goods will be liable to all the accidents inseparable from an exposure in the open air; the damage occasioned by wind; the deposits of insects, birds, &c.; and the spots caused by the falling of blossoms, &c., from the trees usually planted round the bleaching field. These spots are most frequently waxy in their nature, and fix themselves upon the cloth, sometimes causing sad defects in the printing operations.

As the process has been much improved of late years, by first submitting the goods to the method of scouring described in Chapter I., which diminishes the duration of the exposure in the meadows, and, consequently, the accompanying inconveniences; it is still sometimes employed in spring, which is the most favourable season for bleaching, and that during which the operations are less brisk in print-works. Since 1785, however, the open air process has been generally replaced by that proposed by Berthollet, and based upon the decolouring property of chlorine. This process, which has none of the drawbacks attending the preceding one, and which is equally applicable at all seasons of the year, is now conducted in a very regular and rapid manner, so much so, indeed, as to far surpass what the inventor expected from it; but if Widmer, Welter, Descroizils, Haussmann, in France; Watt, Henry, Cooper, in England; at the outset successfully employed it, many other manufacturers decried it, protesting it was liable to many accidents, which might, nevertheless, be easily prevented by a little more knowledge and skill!

Berthollet's process, indeed, at the time it was first made public, was complicated by the operation of preparing the chlorine, which is not now carried on at bleaching works; the apparatus used in this preparation being more or less imperfect, the attendants were frequently exposed to exhalations which rendered it impossible for them to work; whilst, on the other hand, the chlorine employed not being always of a proper strength, the goods became either burnt or unequally bleached.

Besides these drawbacks, there were others still more likely to discredit the new process. It not having been decided, as it now is, that the goods should first be freed from fatty matters, before submitting them to the decolouring agent, bleachers began by applying the chlorine, before having completely removed these fatty and resinous matters, and they necessarily impeded its action, retaining the colouring matter in the fabric and merely modifying it, so that it reappeared in spots during the printing processes, and occasioned the manufacturer as great losses as if the fabric had been deteriorated.

In our times, with the exception of what is due to the carelessness and inattention of the attendants, there is nothing of the above nature to fear, when it is known both what is the action of the chlorine in the important operations of decolouring the fabric, and the conditions in which it may be most advantageously employed. It is therefore our present task to study the first, and specify the second.

The Action of Chlorine in the Decolouration of Goods. Berthollet, considering with his contemporaries that chlorine was a combination of oxygen and muriatic acid, which he named an oxygenated muriatic acid body, compared its action to that of air, with this restriction, however, that, in this compound, the oxygen was condensed in very great quantity, and in a particular manner, so as to have an infinitely more energetic action upon tissues than when it is more at liberty, as in the air. This way of considering the action of chlorine must naturally be laid aside, when the simple nature of this substance is known; but as, at the same time, we become aware of its great affinity for hydrogen, we also perceive that it decolourizes tissues by seizing upon a part of the hydrogen which they contain, and that, by changing the ratio of their constituent elements, it transforms them into other substances no longer possessing the same properties.

From experiments undertaken to study what grounds this theory might have for support, it was soon seen that it did not possess the desired stability. It has indeed been observed, that colouring matters which are instantly decomposed by moist chlorine when they are wet, may, when they are carefully dried, remain unaltered in an atmosphere of chlorine equally dry, provided the experiment is carried on in the dark, for under the influence of light there is always some effect produced, differing, however, from that which takes place under the influence of water, inasmuch as that, with a certain quantity of hydrochloric acid gas, one or more organic products are obtained, according to the duration of the action of the chlorine, in which this is found as a constituent element. It is not possible, then, in the actual state of things, to maintain that, in the bleaching process, the chlorine acts directly upon the hydrogen of the colouring matter, since it is proved that the presence of water is indispensable; it must, consequently, be recognised as acting indirectly. There is nothing impossible in the effect of chlorine upon colouring matters being dependent upon the action of one of its decolouring compounds, which in so many cases give up their oxygen, and act powerfully as oxydising agents.

Whatever opinion may be adopted touching the action of chlorine, in what state will it be most advantageously employed? In a free state, or in a state of combination? As for ourselves, we have no doubt upon this point, reiterated experiments having demonstrated that, when immersed in chlorine gas, humid tissues become perfectly bleached without experiencing any further alteration. Notwithstanding, in the first applications to bleaching of this agent, the preference was almost always given to liquid chlorine, probably because, for want of apparatus properly suited to the operation, it was feared that the attendants might suffer from the irritation produced by chlorine gas upon the respiratory organs; but nothing is easier than to avoid this inconvenience. It is sufficient to fit up in the bleaching works a long leaden funnel which must be filled with chlorine gas, the pipe from the gas-producing apparatus being at the lower part of the funnel, so as to displace the air by degrees; at the base of the funnel there should be a shallow vessel of water to absorb the hydrochlorate formed. The pieces to be bleached may be introduced into the funnel through a slit, made at the top of one of the sides, and made to circulate so as finally to emerge at an opening opposite to the entrance; these two openings may be closed by water, to prevent all escape of gas. As the goods treated in this manner are always well bleached, this process, the promptitude and good results of which leave nothing to be desired, would without contradiction be preferable to any other, but that it requires the preparation of the chlorine

gas on the spot where it is consumed, and this operation is always expensive when not connected with the manufacture of soda.

Liquid Chlorine.—Liquid chlorine also perfectly bleaches fabrics, and they may always be immersed in it without risk, by regulating the strength of the solution; it was, indeed, in this state that Berthollet first recommended its use; it has, however, been abandoned for several reasons:—

1st, Because, without suitable apparatus to effect the solution of the chlorine, there is constantly a loss of a certain quantity of this substance; and because, from the necessity of operating under a pretty high pressure, strong emanations cannot be prevented.

2d, Because it is too expensive, its preparation entailing the same expenses as that of gaseous chlorine; and its application rendering necessary also the purchase of costly stone vessels, or a continual outlay for wooden vessels.

In 1832, this mode of bleaching was still followed in the department of the Oise, in France. The chlorine was dissolved in water; it was then immediately conveyed into brick troughs, where it was brought to such a state of dilution that its odour was scarcely perceptible, and the goods were put to macerate for a certain time in these troughs, from which they were withdrawn to submit them to the subsequent operations.

Combined Chlorine.—It is in the state of *chloride of lime* that chlorine is at present applied for the bleaching of fabrics. The chloride of lime has not a decolouring effect by itself, for, dissolved and brought into contact with a colouring matter, it produces only slight modifications upon it so long as the mixture is preserved from contact with air; but, with the intervention of an acid, or of air which contains carbonic acid, it is decomposed, and the colouring matter is destroyed; the acid, seizing the lime, sets at liberty the chlorine, or chlorous acid. It is obvious, therefore, that if the chloride of lime were not accompanied by an auxiliary, it would not produce the desired effect in its application to bleaching. That which is associated with it for this purpose is sometimes air, the action of which is slow—and sometimes sulphuric or hydrochloric acid diluted with water, the effect of which is instantaneous.

It would seem, at first sight, that a concentrated solution of chloride of lime, which does not destroy colours, might *a fortiori* be brought into contact with the textile fibre without injuring it. Experience proves, however, that this is not the case, for a stuff impregnated with chloride of lime, even pretty much diluted with water, which would appear at first view to have undergone no alteration, is always found to crumble into powder at last. A fabric plunged into a boiling solution of this same chloride, is still more quickly deteriorated. In employing the chloride of lime, the manufacturer should, therefore, never lose sight of the fact, that the deterioration of the textile fibre will be more rapid, in proportion as the solution is more concentrated, the temperature more elevated, and the contact of the fabric with the chlorine more prolonged.

There is yet another method of employing chlorine for the decolouring of fabrics: it is by forming on the goods themselves, by means of an excess of chlorine, the chloroxide which destroys all the organic matters. For this purpose, the goods being impregnated with hydrated potassa, of a determinate strength, are immersed in an atmosphere of gaseous chlorine, which reacts on the oxide, and displaces the oxygen. This last then produces the effect of destroying the colouring matter, but injuring the goods at the same time. This plan, therefore, is not to be recommended.

With few exceptions, it is always the dry chloride of lime which is employed in bleachworks, because it is easier of transport, and, consequently, less expensive than liquid chlorine. Its solution is effected in a stone vat, wooden vessels being too easily attacked; and, to render the solution more rapid and more complete, a wooden cask is placed immediately over this vat, traversed by an axis, at one of the extremities of which is a winch, the cask being pierced over its whole surface with a multitude of holes about an inch square. This cask, which dips from four to six inches in the water contained in the vat, has on one of its staves an opening, which is fitted exactly by a lid, and by which the dry chloride of lime is introduced along with some flints. This opening being shut, the cask is put in motion by the winch attached to its axis, and the flints, rubbing against each other, bray and pulverise the chloride of lime, the solution of which is thus promoted. As it is of importance that the latter be clear and transparent, it is left to settle; without this precaution, there would be a risk of burning the goods, and of producing holes in them at certain places—an accident of only too frequent occurrence in bleaching muslins. In fact, particles of basic chlorate, or of a compound not yet examined, and which are accidentally met with in the chloride of lime of commerce, deposit in the meshes of the fabric, especially when the latter is open in its texture; and, when the goods are passed into an acid bath to render the chloride of lime active, such insoluble particles, being decomposed, produce, by the chlorous acid or chloric oxide disengaged, a corresponding number of holes in the fibre. M. Edward Schwartz attributes the deterioration to bubbles of chlorine, but, from direct experiments, we are convinced that this opinion is not well founded; for muslins can remain some time in humid gaseous chlorine without experiencing any sensible injury; and we have remarked that, on washing with chloride of lime till the action ceases, an insoluble residue is obtained, mixed with more or less lime and calcareous carbonate, which, treated with hydrochloric acid, generates one of the most energetic oxidizing bodies, and which, spread on a fabric afterwards passed into an acid bath, burns it at numerous points.

The chloride of lime being well dissolved, it is diluted with a pretty considerable quantity of water, till it marks, according to the process applied, either 0°, or 1° to 2° of the areometer, or, better still, till it decolorizes once or twice its volume of a solution of indigo. When it has been brought to this point of concentration, the goods are impregnated with it by following one or other of the operations which we are about to indicate, and in which the chloride is employed, sometimes in very dilute solution—in which case its action is more or less slow—sometimes in more concentrated solution, and, in that case, its action is brisk and rapid.

I. *In the first case*, the operation is performed in different ways. By some bleachers two large vats are provided, each sufficient to contain, besides the quantity of liquid required to wet the fabrics, from four to five hundred pieces of calico; the weak solution of chloride of lime is put into one of these vats; the goods, folded into parcels, are then introduced into it, and left in it for some hours. When the immersion has been sufficiently prolonged, the goods are withdrawn piece by piece, by means of a hook, and are exposed to the air for a certain time, to prolong the slow and progressive action of the chloride. This contact of the chloride with the goods is more especially with the view of making it penetrate uniformly into all the pores of the fabric, so that the chlorine, at the instant of its liberation, may not exercise its action only at the surface of the fibre. When this contact has been sufficiently prolonged, the goods are plunged into an acid bath which is contained in the second vat; the chloride of lime which they still retain is decomposed, and the chlorine, being set at liberty, produces all its effect; the goods are then withdrawn and rinsed. This process is still employed in France. Another and a better method is to place the goods for some hours in wooden troughs lined with lead, which are filled with liquid chloride of lime. Each of these vats is surmounted by a roller, by means of which motion is communicated to the pieces, to multiply the points of contact during the time that they remain in the bath. On withdrawing them, they are made to pass between two squeezing rollers, placed on the side of one of the end vats, and the excess of chloride of lime returns into the vat by an inclined plane which is immediately under these rollers. The goods are afterwards passed into an acid bath—a process always adopted—to decompose the chloride, and set the chlorine at liberty.

II. *In the second case*, the bath of chloride of lime is used at such a degree of concentration, that it would be dangerous to allow the goods to remain in it for any length of time; they are, therefore, simply passed through this bath, and that they may be thoroughly impregnated, and in an equal manner, they are dipped and expressed several times, and submitted after each immersion to the action of two squeezing rollers. When

this operation is finished, they are passed into an acid bath contained in a tub which is placed under a wooden chimney intended to convey off the chlorine which always exhales in greater or less quantity during such an operation.

The choice between these two methods of making the chloride of lime act, is not difficult. In the first, the operation, though slow indeed, is at least performed with economy, without danger to the goods, or inconvenience to the workmen; in the second, on the contrary, the expense in chlorine and in acid is more considerable, and there is always danger to the fabrics, however unremitted may be the attention to the process. The only advantage which this method can claim, consists in the despatch and regularity attending it, and which admit of connecting the bleaching operations so as to render them continuous; but the same results might be attained with the chloride of lime extremely weak, applied warm; besides, that the chloride would penetrate more completely into the pores of the fabric, this method would dispense with those repeated immersions and pressings always required, when the operation is performed cold, to displace the water which remains in the pores of the fabric, in consequence of the operations of scouring. Treated with weak chloride of lime, brought to the temperature of 70° to 80° Cent. (or 160° to 180° Fahr.) the goods would imbibe it almost without difficulty, and the water contained in their pores would be displaced by reason of the difference of its temperature and density, compared to that of the bath.

Whichever of these processes be adopted, the goods, when withdrawn from the acid bath, should be carefully rinsed. They are then submitted to the action of a lie of carbonate of soda, with the view of dissolving the portion of colouring matter which the chloride has already modified, and still adhering to the fabric. After this second lixiviation, the goods, according to the degree of whiteness which it is desired to impart to them, and according to the resistance which their fibre presents to the bleaching operations, are a second time passed through the chloride in the same manner as before, followed in like manner also by another immersion in the acid bath, after which they are rinsed for another lixiviation in the carbonate of soda.

When the goods have attained the degree of whiteness desired, they are submitted to the operation of *souring*, which consists in dipping them into a warm bath of dilute sulphuric acid, to prevent them from becoming in the long run more or less yellow, by the action exerted by the air on the resinous matter which they always contain, and which the chlorine only temporarily decolorizes—a matter which, although insoluble in alkalies, dissolves with heat in the acids. This acid immersion of the goods has further the effect of dissolving the oxides, such as the lime, the alumina, and the iron, that adhere to the fabric, and frequently produce annoying results in the operations of dyeing. This bath is applied in one or other of the following methods:—

When a steam generator is not at command, a sheet of lead is taken, and the four sides of it are folded up, so as to make a basin or trough; this is placed over a furnace, taking care, in order to preserve it from the action of heat sufficient to melt the lead, to put under the bars iron plates, intended to diffuse the heat uniformly. When, on the contrary, a steam generator may be had, a wooden vat or trough is provided, lined internally with lead, into which the steam is conveyed by a pipe of the same metal. To 110 gallons of water, heated to 40° to 50° Cent. (or 100° to 120° Fahr.), which is introduced into one or other of these vessels, are added 27½ gallons of sulphuric acid of commerce, previously diluted with a certain quantity of water, to free it by elutriation from the sulphate of lead, which it may hold in solution; and, by means of a roller, which ought to be erected over the vessels, from 12 to 15 pieces are passed through it, giving them 1½ to 2 turns; they are then withdrawn, at the same time adding to the bath, to restore its original strength, diminished by the dipping of the goods, a quantity of acid varying from six to sixteen ounces (troy), according as the pieces had been more or less cleansed and rinsed after the last lixiviation. After this operation, the last of the bleaching process, the goods should be washed with the greatest care, otherwise, as desiccation ensued, the sulphuric acid, becoming concentrated on the fibres, would reduce them to powder.

BOTANY.

CHAPTER XVI.

SECRETIONS—(CONTINUED.)

As it is impossible, within cursory limits, to do justice to the multitude of vegetable products, we subjoin a set of epitomised views for the purpose of indicating their variety and importance.

III. Vegetable Acids do not present any constant analogy as to their form, some being liquid at common temperatures, transparent, inodorous, or volatile, while others are respectively solid, coloured, pungent, or fixed. The acids are never simple in their properties: they are, consequently, compounds of two or three of the elements, oxygen and hydrogen being the most general; and, according to their various proportions, different acid substances are produced, if they contain more oxygen than is required to form water with their hydrogen. The following atomic analysis from Meyen (Pflanzen Physiologie, band ii., p. 301), shows the change which the elements undergo in the production of acid from the starch or other constituents of plants:—

	Amylum or starch.	Citric acid.	Tartaric acid.	Acetic acid.	Malic acid.	Equisetic acid.
Carbon, . .	12	4	4	4	4	4
Oxygen, . .	10	4	5	3	4	3
Hydrogen, .	20	4	4	6	4	2

More than one acid may be formed in the same individual; in the leaves of Cicer arietinum, or Chickpea, for example, several are present. They are all characterized by being decomposed by heat, by solubility in water, by changing the blue, green, and purple colours of vegetables to a bright red, and by uniting with alkalies and earthy and metallic oxides to form salts.

Oxalic acid is the most highly oxygenated of all the vegetable acids. It was discovered by Scheele in 1766, in wood sorrel (Oxalis aceto-sella). It is also found in common sorrel (Rumex acetosa), and sheep's sorrel (R. aceto-sella), in kidney-shaped-leaved oxyria (O. remiformis), and in the fluid of the pitcher of the Ceylonese plant, Nepenthes distillatoria. In these instances, it is associated with binoxalate of potash; but in others, the combination is with lime, as in rhubarb (Rheum palmatum), and several species of Parmelia and Variolaria. Many lichens, indeed, as Patellaria immersa, are observed in process of time to penetrate into the calcareous rocks, on which they become fixed; the excavation being effected by the oxalic acid they secrete acting on the carbonate of lime. In rocks not calcareous, such plants always remain on the surface.

Acetic acid exists spontaneously in the form of salts in the juices of many plants. The Sambucus nigra, or Black elder, the Phœnix dactilifera, or Common Date palm, and the Rhus typhinum, or Virginian sumach, are notable for the quantities they supply. It is also obtained artificially both by the fermentation of saccharine matter, and by the destructive distillation of wood.

Tartaric acid was first obtained by Scheele, in a state of separation and purity, in 1769. It exists in the sap of several acidulous fruits, in usual combination with lime or potassa, and is entirely confined to the vegetable kingdom. It is found free in tamarinds, in the unripe grape, and in pepper; and in a state of combination, in tamarinds, ripe grapes, gooseberries, mulberries, squill, dandelion, stinking goosefoot (Chenopodium vulvaria), and in various species of pines, &c. It is present in vine leaves and tendrils; and particularly abounds in the bitartrate of potash, usually called cream of tartar, which is a salt deposited from grape juice, on the sides of the press and

casks, during the making and ripening of wines. It is, however, mostly prepared for use by artificial processes.

Hydrocyanic acid, vulgarly called Prussic acid, abounds in the drupaceous family of vegetables, in combination with certain essential oils. It is formed in the leaves of the cherry-laurel, bird-cherry, and others, and is easily obtained from them by a process of distillation. It occurs in the kernels of most stone fruits, as peach, plum, and bitter almond. It is even secreted in the seeds of the apple. The taste and smell of all these substances, when bruised, is at once characteristic.

Citric acid abounds in the fruit of the genus Citrus. It is easily obtained in the form of crystals from the juice of limes, lemons, oranges, and the pulp of tamarinds. The average proportion furnished by a gallon of good lemon juice is about 8 ounces. It occurs in a state of combination in many other fruits, as red-currant, raspberry, gooseberry, unripe grapes, common bird-cherry, cranberry, whortleberry, bitter sweet-berry, &c.

Malic acid received its name from having been first obtained in considerable quantity from the juice of apples; but it is also called Sorbic acid, from being procured from the berries of Sorbus aucuparia, or Service-tree. It exists in many other fruits, as in the berries of the mountain-ash and hawthorn, in gooseberry, and in the leaves of the house-leek. In short, it is associated with tartaric and citric acids in most acidulous fruits.

Gallic acid is named from the gall-nuts, in which it is found, by exposing a powdered infusion for four or five weeks to the action of the air, at a temperature of 60° or 70°. It exists largely in the seeds of the Mango-tree, and in lesser proportion in most astringent vegetables.

Meconic acid (μήκων, wild poppy) is found only as yet combined in opium. It was first distinctly described by Robiquet.

Tannic acid is so called from combining with the skins of animals in tanning, by which their pores are rendered impervious to the action of water and sources of decay. By reddening litmus and combining with salts, there can be no doubt of its possessing the properties of an acid. It is derivable from every part of Quercus, or oaks, but especially from the bark and gall-nuts. It also exists in such vegetable extracts as catechu, and is an active principle in willow-bark, horse-chestnut husks, green acorn cups, and in tea. To this we may add, that *Suberic acid* is an artificial substance produced by treating rasped cork, or the bark of Quercus suber, with dilute nitric acid. An analogous principle is termed *Kinic acid*, derived, it is probable, from the East Indian name, Kini or Kuenee, applied to an exudation of Pterocarpus.

Lactic acid is found in the juice of beet-root and other plants, but belongs also as a property to milk and various other animal fluids.

Formic acid, excreted under irritation by ants (formica), is secreted in peach kernels. Being capable of production from the peroxydizement of various vegetable substances, it is obtained by chemical means.

Phosphoric acid, throughout the three kingdoms of nature, is least abundant among vegetables. It is, however, very generally diffused in plants, and forms an important medium of their organization.

There are numerous other acids of a vegetable nature which remain for description, such as the pectic, carbazotic, mucic, saclactic, stearic, margaric, &c.; but being of little practical utility, we refrain from entering upon them.

IV. Vegetable Alkaloids.—The Arabians gave the name of al-kali to a plant, by burning which they were the first to obtain or to characterize a saline mass containing a particular alkali; and the same term has been continued to denote that important class of substances which possess similar properties. Those hitherto found out, are ammonia, existing in animal fluids, and composed of hydrogen and azote in volatile proportions, without any intermixture of oxygen; and fixed compounds of certain metals and oxygen, comprising lithia, potash, and soda. These, however, are inorganic in their structure, and distinguished from an organic order of alkalies, or vegeto-alkalies, produced in plants during vegetation; and as far as ascertained, quaternary compounds of oxygen, hydrogen, carbon, and azote, united in extremely variable proportions. It is to this latter order of objects that the name alkaloid is properly given. In stinging plants, for instance, as cowhage (Dolichos pruriens), and nettle (Urtica dioica), which puncture the skin by their hardened points, contrived by barbs, hooks, or spiral grooves to facilitate insertion, a tubular hair secretes a caustic fluid for infusing into the wound. This acrid secretion, in the case of nettle, has been ascertained by M. De Candolle, jun., to be a vegetable alkali. They differ both from alkalies proper, and from the earths to which alkalies are sometimes united as bases, not only in exhibiting alkaline attributes in a lower degree of power, but chiefly in being the active principles of plants requiring a vital power for their formation. Their discovery by Sertuerner, a German chemist, may be dated from 1817; but, for ten years after, little or no notice was paid to the subject, till, revived by the Institute of France, the study of the alkaloids of plants remarkable for their properties has been eagerly prosecuted and usefully applied both in the arts and manufactures.

All the alkaloids are characterized by the properties of the plants in which they are produced. Sometimes only one in number is secreted; but occasionally several are present in the same plant, as in Opium. A large portion of them are solid, or capable of crystallizing; some are amorphous, as Aconitin; others are liquid, or form gummy masses, as Conin and Nicotin. A few are tasteless, but the majority are bitter and acrid, and even their least appreciable solution imparts these qualities to a menstruum. With the exception of Curarin and Nicotin, they are little soluble in water, and only slightly more so in alcohol. At a moderate temperature they are decomposed or evaporated with the evolution of ammonia. They possess the property of restoring the colour of turnsole when reddened by acids, and they turn the sirup of violets green. But their most remarkable characteristic is that of never being found insulated, but always existing in combination with acids; and though their capacity of saturation be inconsiderable, this union neutralizes—rarely, however, in a complete degree—the separate powers of the acids, so that salts are formed, which, from their greater pliability, are much more applicable to medicinal purposes than the primary alkaloid. The production of neutral compounds of this nature is plentifully carried on among all vegetables; they are readily seen in the cells of cactus and squill, and are the occasion of the grittiness of rhubarb when chewed. The salts of more general occurrence are sulphates, bisulphates, and desulphates; chlorates and hydrochlorates; nitrates, acetates, oxalates, and phosphates.

The atomic constitution of some of the principal alkaloids is given in the following table :—

	Morphin.	Conin.	Strychnin.	Brucin.	Quinin.	Cinchonin.	Veratrin.
Carbon, ...	34	32	30	32	20	20	34
Hydrogen, . . .	36	39	32	36	24	23	22
Nitrogen, . . .	2	2	2	2	2	2	1
Oxygen, . . .	6	5	3	6	2	1	6

Morphin, the most important of the vegetable alkalies, was first observed by Sertuerner, and afterwards accurately determined by Robiquet, as the chief narcotic principle of opium (Papaver somniferum). It is precipitated in a flosculent state, which, on standing and stirring, assumes the forms of rectangular and rhombic crystals, or is more generally derived into flattened six-sided prisms, small, brilliant, and colourless. There are other associated principles in opium of an alkaline nature, such as *Codein*, discovered by Robiquet, and *Paramorphin*, frequently also called Thebaïn, discovered by Thiboumerey. The atomic analysis of these associates, according to Löwic, is Codeïn $C^{35} H^{20} O^{5} N$, and Paramorphin $C^{25} H^{14} O^{3} N$.

Strychnin and *Brucin* were discovered in 1818 by Pelletier and Caventou, in the seeds of several species of the genus Strychnos, especially S. nux vomica, or poison-nut, and S.

Ignatia (St. Ignatius' Bean). They have since been found in the bark of these plants, in the seeds of S. colubrina, or snakewood; in the juice of S. tieuté, the Java poison; and in that of S. guianensis, or toxicaria, the Wourali poison of Guiana. From these composite bodies, the alkaloids may be respectively obtained perfectly pure. An alcoholic solution of strychnin spontaneously evaporates and crystallizes in small white quadrilateral prisms, terminated by pyramids. Brucin was named from the supposition that it is to be obtained from Brucea anti-dysenterica, the seeds of which were first brought into England from Abyssinia, by James Bruce, Esq., the celebrated traveller, and grown in the Paris and Kew gardens towards the conclusion of last century. This alkaloid is obtained in clear, delicate, pearly scales.

Cinchonin and *Quinin*. The late Dr. Duncan of Edinburgh, in the year 1803, procured from the barks of the officinal species of Cinchona, a peculiar principle capable of forming precipitates with tannin. Gomez of Lisbon, in 1810, obtained a crystalline substance invested with the properties that had attracted his precursor. But in 1820 the analysis was completed by Pelletier and Caventou, who, in the course of their researches, discovered another alkaloid contained in Cinchona, which they termed Quina. To this discovery Pelletier and Corriol, in 1829, added a third alkaloid (Aricin), which they obtained from a species of Cinchona, recently introduced from Cuzco, in the southern parts of Lower Peru. Lastly, in 1842, Manzini laid claim to the discovery of a fourth alkaloid, called Cinchovatina, in the species or variety known as *ash*, imported from the Columbian town Jaen, and the adjacent Peruvian territories. Amongst these, undoubtedly the most interesting and important are the two first, which have become noted for their powerfully febrifuge qualities. The yellow bark yields quinin in abundance: cinchonin predominates in the pale or red. Though analogous to each other, they occupy the same relation as potash and soda, but may be entirely separated from each other by means of either sulphuric acid or boiling water. Cinchonin has one atom of hydrogen and one of oxygen less than quinin. The one is slightly acid, the other intensely bitter. The first readily crystallizes in colourless four-sided prisms; while the other is rarely seen except in the form of amorphous powder, and is made to pass with difficulty into needle-shaped crystals.

Veratrin is the alkaloidal principle of Veratrum sabadilla, an inhabitant of Mexico and the West Indian islands. It was obtained by Meissner, in the year 1819, from the seeds of this plant; and about the same time by Pelletier and Caventou in the root of Veratrum album (white hellebore). According to Schiede (Travels in Mexico, &c.), it is also produced by a plant of the same natural family inhabiting the eastern slope of the Jalapa Andes, and named Helonias (Don) or Asagraca (Lindley) officinalis. The action of Colchicum autumnale (autumn crocus) has been found by Geiger and Hesse to depend on an analogous principle termed Colchicin. The whole of these are irritant poisons, of valuable application when regulated by science.

Emetin was discovered by Pelletier in 1817, in the roots of Caphaëlis ipecacuanha. It consists of $C^{35} H^{25} O^{9} N^{1}$.

We can only further refer, consistently with the limits of this notice, to *Curarin*, *Nicotin*, *Esenbeckin*, *Aconitin*, *Coneïn*, *Crotonin*, *Buxin*, *Eupatorin*, *Corticin* and *Populin*, *Solanin*, *Atropin*, *Bebeerin*, &c.

V. Vegetable Oils form an important department of the secreted matters of plants. They are not indiscriminately diffused through the cellular texture, but are contained in distinct vesicles of extreme minuteness. The cavities in which they are deposited are sometimes easily detected, as in the rind of the orange; but in other cases they are too evasive to yield to such a test, and require to be elicited by a more artful process. In point of composition, oils either consist of olefiant gas and water, or have a reference to that combination. The quantity of hydrogen which they contain is greater than is required to form water with the oxygen present, and this constitution renders them more inflammable than either sugar or starch. For the same reason they are extensively employed, not only to produce both heat and light by ordinary combustion, but, on account of the physiological property of promoting animal heat, they form an essential element in the food of the inhabitants of cold climates. Besides inflammability, they are generally characterized by being unctuous to the touch, and by insolubility in water.

Oils have fallen to be arranged under two distinct divisions, —the fixed or fat, and the volatile or essential. The first are found principally to occupy the seeds of plants, the fleshy coverings of seeds, or the pulp of the fruit, as in Melia and others; the second series are more extensively diffused throughout the tissues, in fact, through every part except the cotyledons of seeds. The fixed are obtained by crushing or pressure, varied in degree according to the nature of the substance, and sometimes aided by boiling; the volatile, on the other hand, rising in vapour by the agency of heat, are collected by distillation. They differ also in the length of time, according to which they become inert; thus, the one communicate a permanent stain to paper, while the stain which the others communicate disappears by gentle heat. The fixed only in any great degree contribute to the functional movements of life; the volatile appear merely to be of service in modifying the sensation. But the exceptions to which these contrasts are liable, render it necessary to describe each of the orders with a reference to their more peculiar qualities.

The *fixed oils* are not always obtained by simple pressure, but sometimes by boiling the plants in ether, filtering the solution, and afterwards distilling off the ether, when the oil or fat is found to remain. It is to be observed, that when this form of process is employed to procure fixed oil, it never rises, but always falls to the bottom. The fixed oils are nearly devoid of taste and smell. They are lighter than water, and though not uniting with it, may be suspended in the form of emulsion, by means of sugar or mucilage. The mucilaginous matters with which they are mixed, subject them to become rancid when exposed to the air. They begin to boil at about 600°, but suffer partial decomposition at a lower temperature. They form soap with alkalies, and coagulate with salts. Some of the kinds, as linseed oil, from absorbing oxygen when heated, acquire the property of drying; and such is the heat which accompanies this action, if abundant and rapid, that combustion often ensues in warehouses and manufactories where drying oils have been accumulated; these properties, however, make them available in oil paintings; and when mixed with lampblack, they also constitute printers' ink.

1. *Fixed oils* contain two proximate principles, which have been analysed by Chevreul and others, and denominated by the terms Stearin and Elaïn, the one nearly solid and the other liquid at common temperatures. The degree of cohesion of different oils depends on the proportions in which these constituents are united; and this composition not only solves their comparative consistence, but provides a ready expedient for varying the mechanical properties of fat, according to circumstances. Stearin (στέαρ, fat) is a white friable substance, soft to the touch, but not greasy. It is the chief part of fat, and may be separated in the solid form at 25°. It is brittle, partly soluble in cold, but entirely soluble in boiling alcohol or ether, in which it melts at about 140° or 145° F., and on cooling solidifies into an uncrystalline mass like wax. It appears to consist of a peculiar acid, called stearic acid, and the principle termed, on account of its sweetness, Glycerin. Associated with stearin in the solid part of fat is another constituent, named Margarin (μαργαρίτης, a pearl), on account of its lustre. It occurs both in animal and vegetable oils, and differs from stearin only in being more fusible; the animal variety melting at 116°, and that from vegetables at 82°. Olive oil contains a large proportion of margarin. Elaïn, sometimes called Oleïn, is the fluid part of oils. It is colourless, and has scarcely any taste or smell. It concretes at 20° to 27° F., and crystallizes in needles. It is soluble to any extent in ether. Specific gravity 0·98. It consists of a characteristic acid named oleïc acid, besides glycerin and margaric acid. It does not readily spoil by action of the air; and, on account of the low temperature at which it congeals, is employed in lubricating the wheels of watches. But it will be useful to particularise a few examples of each of these kinds, the names being after the plants from which the oils are obtained.

(1.) Solid fixed oils :—

Palm oil; Elais guineensis.
Cocoa-nut oil; Cocos nucifera.
Sweet-bay oil; Laurus nobilis.
Vegetable batter; Various species of Bassia.

(2.) Fluid fixed oils :—

Olive oil; Alea europea.
Linseed oil; Linum usitatissimum.
Hempseed oil; Cannabis sativa.
Castor oil; Ricinus communis.
Almond oil; Amygdalus communis.

The Apricot and other Rosaceous plants store up a large quantity of this kind of oil.

Several of the family of Compositæ secrete an immense amount; as, Sunflower, Jerusalem artichoke, Bastard saffron, Verbesina sativa of India, and Madia sativa.

Oil is also abundant in the melon, gourd, cucumber, and most of the Cucurbitaceæ.

The mustard-seed, rape-seed, and colza-seed oils belong to the Ceruciferæ.

Hazel-nut, beech-nut, and walnut oils, are among the Amentaceæ.

In addition to these, poppy oil, ben-nut oil, ground-nut oil, and physic-nut oil, are well known. Oils are also yielded by the seeds of the Cotton plant, Tea tree, and some of the Camellias. Most of our cultivated plants have an appreciable quantity of yellow-coloured oil; and the proportion contained in 100 lbs. of some kinds, according to Johnston, is as follows :—

Wheat flour (fine), ...	2 to 4 lbs.
Barley, ...	2½ "
Oats, ...	5 to 6 "
Indian corn, ...	5 to 9 "
Beans and peas, . . .	2 to 3 "
Wheat straw, ...	2 to 3 "
Meadow hay, ...	2 to 5 "
Clover hay, ...	3 "

These oils not unfrequently communicate the odour peculiar to the burnt grain.

There are two substances allied to the fixed oils which fall to be embraced in this notice; namely, wax and chlorophylle.

(*a.*) *Wax* is a fusible substance, and insoluble in water. A strong heat decomposes it into carbon, hydrogen, and oxygen; and Ettling states the equivalents to be $C^{18} H^{19} O^1$. Hess affirms that it is essentially a homogeneous body; but, according to John, it consists of two proximate principles:—Cerin, fusible at 143°, soluble in boiling alcohol, and convertible by caustic potash into margarate of potash; and a waxy body called Cerain, which melts at 158°: the second principle is Myricin, fusible at 149°, sparingly soluble in boiling alcohol, and incapable of forming a soap with alkalies. Wax envelopes many parts of plants, overspreading the bracts of Musa paradisiaca, or plantain tree, and giving rise to the bloom of grapes and plums. It is to be seen also on the leaves of species of the Cycad, Encephalartos, and Ilex aquifolium, or common holly. Sometimes a bluish powder, waterproof, is strewed on the plant, as on the leaves of Mesembryanthemum, or fig marigold, Atriplex, or orache, and Brassica, or cabbage; and so effective is this provision, that it has been compared to the plumage of the cygnet and other aquatic birds, who rise out of the water without being wetted, by reason of the oily secretion with which they are smeared. Wax commonly occurs in the pollen of flowers, and is supplied in abundance by certain plants, such as Myrica cerifera, wax myrtle, or bay tree, a native of the United States of America, where the wax is collected from the fruit, and used as a substitute for bees-wax, or for making candles. A thick coating of wax invests the whole of the stems of Ceroxylon and Iriartea, on the former of which the American Spaniards have bestowed the name of Palma de cera, or wax palm. Below the snow-capped mountains of San Juan and Quindiu, in South America, the Ceroxylon elevates its majestic trunk to the height of 180 feet, incrusted all over with an exudation, one-third of which was ascertained by Vauquelin to consist of wax, only a little more brittle than bees-wax. Such plants are rendered completely waterproof by the secretion thus spread upon their surface; and many aquatic races, as Batrachospermum, are in like manner rendered slippery and impermeable to water by a viscid coating.

(*b.*) *Chlorophylle* (χλωρὸς, green, and φύλλον, leaf) floats in the fluid of cells, accompanied by starch grains and other ingredients. There are several kinds of colouring matters produced during vegetation, but chlorophylle is the name given to the matter which greens the leaves and stems. In particular cases or stages, it is a semifluid gelatinous substance without determinate figure, but more usually assumes a granular form, each particle being either separate or united in masses. Like the oils, it is soluble in alcohol or ether, but insoluble in water. Mohl (Ann. Sc. Nat. série 2, Bot. ix. 162) found that the action of iodine renders it brown. When in a state of separation, it is bleached by the action of chlorine, or by exposure to light. A similar effect is produced by acids; and it is their formation and action in autumn that causes the tints which are assumed in the sere and yellow leaf. Chlorophylle is converted into soap by alkalies, which also restore the green when reddened by acids.

2. *Volatile or essential oils* are distinguished from the expressed oils by a more perfect fluidity, greater combustibility, penetrating odour, sometimes aromatic, a fragrant and acrid taste, and by being volatilized *per se* without decomposition. They dissolve sulphur in large quantity, forming the deep brown liquid called balsam of sulphur. They also dissolve phosphorus. In some instances they are obtained by pressure without the application of heat, as oils of lemons, oranges, and bergamot. With such exceptions, however, they are produced by distillation; and the point at which they may be distilled with water is 212°, although they boil at a much higher; indeed, they are volatilized without water at 300°. The distillation is effected by putting the herb or bark, reduced to fragments, into a still with water, when the oil and water are volatilized and condensed together. For this purpose the bark of wood is employed, the wood itself, leaves, flowers, and rind of fruits. The volatile oils, like the fixed, contain a harder and softer principle, named Stearopten and Elæopten. The list of oils of this latter order is too extensive for enumeration; we can only instance—

Turpentine, . . .	from	various species of Pinus and Abies.
Cinnamon, . . .	"	Cinnamomum zeylanicum.
Cloves, ...	"	Caryophyllus aromaticus.
Garlic, ...	"	Allium cepa.
Nutmeg, ...	"	Myristica moschata.
Mustard, . . .	"	Sinapis nigra.
Juniper, ...	"	Juniperus communis.
Otto or attar of roses,	"	Rosa centifolia and others.
Peppermint, . .	"	Menthia viridis.
Caraway, . . .	"	Carum carui.
Bitter almond, . .	"	Amygdalus communis
Fennel, ...	"	Fœniculum officinale.
Star-anise, . . .	"	Illicium anisatum.
Cedar wood, . .	"	Larix cedrus.
Pepper, ...	"	Piper nigrum.
Ginger, ...	"	Zingiber officinale.

The solid principle of the volatile oils is represented by the organic substance called Camphor. This body not only retains its solidity at the ordinary temperature of the air, but on exposure to the air is volatilized without leaving a residuum. It is inflammable, like the other oils, melting at 288° and boiling at 400°. It is insoluble in water and alkalies, but easily dissolved in alcohol, oils, and acids. It is unctuous and somewhat brittle, and has an aromatic smell and taste.

Camphor is obtained from two kinds of laurel, the Cinnamomum camphora and Camphora officinarum. The former is a native of Japan and India; and so abundantly does this secretion occur in the roots, that they are unfit to be used as a spice. The camphor of commerce, however, is chiefly obtained from the second species, which is a native of China, and is largely produced in the island of Formosa, from which it is transmitted in junks to Canton, a distance of about 300 miles, and thence

supplied to the foreign markets. It exists in every part of the plant, the root, stem, branches, and leaves, from which it is procured by means of distillation with water. The pieces are chopped sufficiently small to be thrown into iron vessels covered with earthen or wooden hoods; and when a gradual heat is applied, the substance is volatilized and condensed on rice straws and rushes, which had been introduced for the purpose. On a small scale it may be procured from the live tree in a dry way, by making a transverse incision in the trunk to the depth of some inches: the natives cut, sloping downwards, from above the notch thus made, till they leave a flat horizontal surface: this they hollow out till it is of a capacity to receive a quart; they then put into the hollow a bit of lighted reed for about ten minutes, which stimulates the fluid to that part, and in the space of a night the liquor fills the receptacle prepared for it. In this way the tree continues to yield a smaller quantity for three successive nights, if fire be again applied; but on a few repetitions, it becomes exhausted. The product, from whatever mode obtained, is subjected previously to exportation, and usually also after arrival in this country, to a process of purification by sublimation.

Camphor is likewise procured from two plants belonging to the family Guttiferæ of Decandolle and Dipteraceæ of Lindley, namely, Dipterocarpus camphora and Dryobalanops camphora. These are only found in India and in the eastern islands of the Indian Archipelago, where they form the ornaments of the forest by their majestic size, graceful forms, and beautiful colouring of the flowers and fruit. The camphor obtained from these trees, from an impaired volatility, appears very slowly to decrease in quantity by being kept. It is not produced by distillation, as with the others, but is secreted in crystalline masses within the wood, and the trunk, therefore, has to be split open in order to reach it. In that part of the stem usually occupied by the pith, it is found in the younger plants always associated with a liquid called camphor oil, which has been ascertained by Christison to consist of 94 per cent. of volatile oil, and 6 per cent. of resin, without any camphor; and this oil seems only to be absorbed in trees of a certain age, so as to leave the camphor in solid masses about a foot in length, but they yield none if they have been previously tapped for the oil. Every tree of the ordinary size does not seem to produce it; but when they have attained a circumference of about seven feet or upwards, each, in general, will be found to yield from 11 to 22 lbs. avoirdupois. This kind of camphor is held in great esteem in the East; and the whole produce of Borneo and Sumatra finds a ready but expensive consumpt in China, where this kind is retained and the ordinary camphor exported. The smallest quantity rarely reaches Europe, except as cabinet specimens; and Christison relates (Edinb. Dispen., 1848), that a few years ago a Chinese cattie of it, or about a pound and a quarter avoirdupois, which was purchased for him at Singapore, cost there £7 stg., when laurel-camphor was in this country selling at half-a-crown the pound.

It is to the volatile order of oils that the peculiar smells of plants are owing. Some flowers seem altogether scentless; others, forming a striking minority, have a disagreeable odour, such as the Fungus, Phallus impudicus, Stinking morel, whilst the Asclepiad, Stapelia hirsuta, has a smell so closely resembling carrion that it attracts the flesh flies to lay their eggs on it. But by far the majority of universally distributed plants are possessed of a pleasing or aromatic fragance; and their impression is often indelible, whether caught from the balmy breezes sweeping over the bean fields of a Scottish carse, or from the scents inhaled from the orangeries of Martinique or Cuba, or from the perfume of a coffee plantation, rowed with its jessamine-like flowers on the Port Royal mountains.

> "Ah! where find words whose power,
> To life approaching, may perfume my lay
> With that fine oil—those aromatic gales
> That, inexhaustive, flow continual round!"

The larger proportion of odoriferous species would appear, from the experiments of Schubler and Köhler, to belong to plants having white flowers, and to decrease downwards according to the colours, yellow, red, blue, violet, green, orange, and brown. Such is the connection of light with the property of smelling, that etiolated plants generally lose their odour. A moist atmosphere, relieved by intervals of sunshine, usually elicits the smell of day plants. The night season is the natural period for developing the odours of many species; as, Hesperis tristis, or Night-scented stock; Cestrum nocturnum, Night-smelling cestrum; and Lychnis vespertina, or White-flowered lychnis. In many cases the odour seems to be intercepted or suspended by the moisture of the plant itself, as in Woodruff, where drying is necessary to make it apparent to the sense; while, in other plants, the process of drying or keeping causes the odour to disappear. In Teneriffe Rosewood it is given out by friction, either probably from liberating the oil from its cells, or rendering it sufficiently heated to become diffused.

VI. VEGETABLE RESINS.

Vegetable resins comprise resins proper, gum resins, balsams, and milks.

(1.) *Resins proper* exude from different kinds of plants as a fusible and inflammable secretion. In their first state, they are probably all fluid, but subsequently solidify either by evaporation of some of their volatile parts, or by the absorption of oxygen. They are soluble in oil, but they require alcohol for their perfect solution. When the solubility is effected in cold alcohol, they are termed simple resins; when the alcohol requires to be boiling, they are sub-resins, though these two are often associated in the same substance; and where a quantity of volatile oil conveys a honey-like consistence to the resin, it is denominated soft resin. A fluid condition exists in the turpentines in consequence of the excess of oil that is present, and they are called either turpentines or oleo-resins. Being completely insoluble in water, and therefore calculated to resist its action, the resins are often employed in nature as a means of protecting the young buds from the injurious effects of the weather. In most aquatic plants, in like manner, a viscid coating, slippery to the touch, defends them from the rot of that element.

The list of resins includes:—

1. The products of various species of Pinus and Abies, namely, pitch, frankincense, dammar, turpentine, and colophony.
2. Anime or copal, from Hymenæa courbaril, Vateria indica, &c.
3. Mastic, from Pistacia lentiscus.
4. Elemi, from species of Amyris.
5. Sandaric, from Thuya articulata, Callitris quadrivalvis.
6. Lac, from species of Ficus, Aleurites laccifera, Erythrina monosperma, &c.

(2.) *Gum resins* are resins combined with mucilage, gum, or other vegetable principles. They are of strong smell, brittle, opaque, and infusible. They form transparent solutions with alcohol, but, when treated with water, assume a milky colour. They are—

1. Gamboge, from Cambogia zeylanica.
2. Guaiac, from Guaiacum officinale.
3. Aloes, from species of Aloe.
4. Scammony, from Convolvulus scammonia.
5. Asafœtida, from species of Ferula.
6. Jalapine, from Exogonium purga.
7. Euphorbia, from species of Euphorbia.
8. Myrrh, from species of Balsamodendron.

(3.) *Balsams* are resinous juices united with benzoic acid. Various substances have been ranked, from time to time, under this name; but it is strictly limited to such articles as contain the above acid with a volatile oil and resin. Balsams are chiefly obtained from the Leguminosæ, or pea tribe; the Styraceæ, or storax tribe; and that section of Amentaceæ called Salacineæ, or willow tribe. Some of the balsams are solid; others are viscid liquids. They appear to be only five in number, viz. :—

1. Peru, from Myrospermum peruiferum.
2. Tolu, from Myrospermum toluiferum, or Myroxylon toluifera.
3. Benzoin, from Styrax benzoin.
4. Storax, from Styrax officinalis.
5. Amber, from species of Liquidamber.

(4.) *Milks* are resinous fluids, named from their milky opaque appearance in different plants. They vary in their composition and qualities, according to the plant which supplies them, some being wholesome, others highly acrid, and not a few entirely poisonous. Among the Dicotyledons, the families Euphorbiaceæ, Papaveraceæ, Apocynaceæ, Asclepiadaceæ, Campanulaceæ, Convolvulaceæ, and Artocarpaceæ; and among Monocotyledons, Liliaceæ, Scitaminaceæ, Araceæ, and Alismaceæ, are the orders which secrete milk in most abundance.

As an example, we may notice the Cow tree, described by Humboldt as being peculiar to the Cordilleras of the coast of Caracas. In these places it forms a fine tree, apparently belonging to the natural order Urticaceæ and genus Brosimum, and is an important object, from its nutritious juices, to the poor natives. The milk which flows from its trunk when incised, is similar to that of a cow after calving, and undergoes the same chemical characters.

The milks which have become more notable from their application in the arts and sciences, are as follow:—

1. Opium, from Papaver somniferum. A yellow juice is met with in the Chilidonium or Celandine.
2. Caoutchouc, from Ficus elastica, &c.
3. Gutta percha, from Isonandra gutta.

VII. VEGETABLE COLOURING MATTERS.

Vegetable colouring matters are of a fluid or semi-fluid nature, and are contained in a cellular tissue called the rete, lying immediately below the epidermis. When extracted, they are converted into dyes and pigments, the fixing of which on cloths constitutes the arts of dyeing and calico printing. They are usually arranged under the three primary classes of red, blue, and yellow.

Red dyes are supplied by the roots or wood of Alkanet, Saunder's wood, Dragon tree, Madder, Broad-leaved morinda, Logwood, Brazil wood, and Camwood. By infusion of red cabbage, a colouring matter is obtained which turns red by the action of acids, and green by the action of alkalies.

Yellow dyes are procured from quercitron bark, turmeric, saffron, hickory, and fustic; also from the pulp of the seeds of Arnotto, the stem of Gamboge, Safflower wood, and from the lichen Parmelia parietina.

Blue dyes are furnished from indigo, archil, litmus, &c. This kind of matter is sometimes obtained from certain flowers, fruit, and leaves, by chemical action.

The blending of these several colours produces all the tints and shades which variegate the fields, and clothe with beauty their breathing prospect.

> "But who can paint
> Like Nature? Can imagination boast,
> Amid its gay creation, hues like hers?
> Or can it mix them with that matchless skill,
> And lose them in each other, as appears
> In every bud that blows?"

There are many details of deep interest in the application of this subject, which, from necessity, must be omitted for the present. There is a single reflection, however, which, in closing, we must be allowed to indulge, and it is put in the pertinent words of Scripture—"If God so clothe the grass, which to-day is in the field, and to-morrow is cast into the oven, how much more will he clothe you? O ye of little faith!" Luke xii. 28. The colours of flowers preach to every man a lesson of heaven-depending reliance; and the same providence which demonstrates its concern for their confessed magnificence, proclaims that it is left to us only to surpass them, by seeking the attainment of immortal endowments.

THE HUMAN FORM.

ITS BEAUTY AND JUST PROPORTIONS.

By a Scotch Physician.

ARTICLE I.

It has been very generally admitted that the sculptors of ancient Greece carried the art of representing all that was beautiful in the human form, not only to the very highest perfection, but to a point of excellence never attained, seldom approached, (except by strict copyists, as Canova), and indeed hopelessly beyond all efforts of human art since that singular and almost inexplicable era, when the human mind produced its grandest results in arts, if not in science. All, however, are not agreed as to the surpassing excellence of the Antique statue; I do not speak of the great majority of mankind who, whether from original deficiency of power, or from a want of education, are unequal to the perception of physical beauty; whose taste, if that expression may be applied to them, is either vitiated, low, or non-existing. As well might we submit the works of Mozart and Beethoven to the ears of a Dutch or English rabble. But there are many of avowedly good taste, who either do not see, or affect not to see, this extraordinary beauty in the Antique statue. Now, these persons have reasoned themselves out of their natural instincts in this matter, and, when they write about art, are continually contradicting themselves, reasoning against their own consciences or instinctive feelings. Mr. Haydon, to whom the merit belongs of having called the attention of the nation to the extraordinary merit and beauty of some, at least, of the Elgin marbles, and who clearly was at that moment in advance, in point of judgment and taste, of nearly the whole nation, has, notwithstanding, fallen into the error I now speak of. He seems to have thought it necessary for the elevation of the "Gods he worshipped"—the Theseus, the Ilyssus, the fighting metopes of Phidias—that none other should be compared to them, and none other adored; that they alone constituted "high art in perfection;" and that even "the Antique," which precedes these, possessed not the surpassing excellencies of his adored and adorable "Elgin marbles."

Believing, but with all the deference due to so distinguished a name in art is that of Haydon, and to many others equally celebrated, who agree with him on this and other points—believing these opinions to be to a certain extent erroneous, and that neither Sir Joshua Reynolds, Sir Charles Bell, Mr. Haydon, nor a greater than all these in taste and masculine understanding, Mr. John Bell, had offered any true explanation of the sources or causes of the high admiration expressed by most men of cultivated minds in respect of "the Antique Statues," namely, that they are *unsurpassed* and *unsurpassable*, that they are superior to all other works of art, that they excel in *beauty* most of the Elgin marbles, that there is a something about them divine, if such a word may be used when speaking of this frail tenement of clay, "fashioned out of dust," and doomed to return to its original elements; in short, that all inquires intended to unfold a "Theory of Beauty," applicable to those works, have entirely failed, and that the latest writer on this matter, Sir Charles Bell, in his work on "The Anatomy of Expression," left the subject precisely where he found it, without addition or amendment; believing that, notwithstanding these repeated failures from the time of Pliny to that of Bell, a true "Theory of Beauty" might be discovered by a comparison of the form and realities of these statues with the human form, as it is to be found in nature; and taking for granted, which all, I think, must allow, that humanity has not degenerated, that the human form has not altered in the lapse of a few hundred or even thousand years, that forms, as fine as ever trod the classic land of Greece, are yet to be found everywhere, —I, several years ago, instituted this comparison, and now venture, though with much hesitation, to submit to the public, through the medium of this Journal, a "Theory of Beauty in the Human Form," which, if correct, should apply to all works of art, ancient and modern; to man, wherever found on the surface of the earth—to all races, ancient and modern; a theory, based not on little conceits or exploded metaphysics, but on a simple analysis of the human form in all its phases, and the relation which these phases have to the human mind, or rather to a mind possessing qualities equal to the perception of beauty: an instinctive quality, improveable but not altogether acquirable, like all the other inherent qualities of the human mind.

The term "beauty," when applied to the human form as a whole or in part, has been used in a variety of ways, and, as usual, with great latitude. This vagueness as to its meaning enables metaphysicians to raise endless discussions as to the real nature of beauty: to form artificial systems of power, thought, and action; to ascribe, for example, to accidental, contingent, heterogeneous, and external circumstances, feelings and strength, which are perfectly intrinsic as regards human nature, forming essentially a part of our living existence. Of this character was the "Theory of Alison," based on what was called "the Association of Ideas;" to this theory were also added other conceits, such as, that the "useful was beautiful;" the happy "adaptation or fitness of things," was the source of endless admiration and of feelings of beauty. This conceit was carried to its utmost pitch by Socrates, and of course refuted instantly by the sophists of his day, who for once showed some common sense. It has been revived repeatedly during the last 2000 years, and was at last taken up by Sir Charles Bell and the authors of the Bridgewater Treatises. They endeavoured to conceal the old theory under a new name, but this trick does not affect its real nature, or render it any way the more probable. But the falsity of such theories, as applied to the human form, becomes manifest when any individual portion of human structure falls to be tested strictly by the anatomist, who is acquainted with the antique marbles, the present human form, and the phases which that form undergoes; and who adds to this knowledge of art and structure, a plain analysis of human thought. The term "beautiful" applies strictly to the entire outline of certain human forms; that is, the cultivated mind, and even the mind uninstructed, if, by its intrinsic nature, elevated, discovers certain forms which it declares to be faultless. Such forms are either entirely or partly so. The antique statues of Venus—the Medicean for example; Bacchus, the Ariadne, the Mars, the Antinous, the Niobe, the Diana, are quite faultless; yet, on examining all these closely, he discovers an objection to the hands of the Medicean Venus. He asks how is this? Are these not beautiful hands? Yet are they not like the other parts of the statue; and he soon learns that the hands were restored by Bernini; that they are unworthy of the statue; that they are unworthy even of Bernini himself. But is it not natural for the least reflecting person to say, were there no fine hands on the Italian women which the Italian sculptors from Buonarotti to Canova might have copied, and thus replace the antique hands of the Venus? It appears not. Either no such hands were to be found, or no such artists as the antique sculptor; or (and this is generally admitted as the difficulty of restoring all lost parts in ancient statues) "the theory of the ancients on which they constructed their works has been lost." To those who have not deeply studied the matter, an avowal of this kind must appear quite mysterious; and they very naturally say, were there never then any human beings like these antique statues? And if there never were, how came there to be artists, with thoughts so sublime, and yet so accurate, as to carve figures without any visible type in nature? To imagine a type would require minds equal to the office of the Creator—equal to the creation of a type of human form. No writer (with one exception, and he only approached it) has explained this incomprehensible and altogether unintelligible anomaly. According to some, the ancient sculptor selected all the finest forms he could muster, choosing from them the beauties of individual parts, and adding them to his ideal figure. This theory still lingers about the schools; but wherever such a system is tried, it could only give rise to monsters, not the less monstrous that in some portions they were beautiful. But here these authors forgot to state in what the beauty of their individual parts consisted. The female head, when beautiful, must be small, really and comparatively; the feet and hands small, the loins broad and full, the arms and limbs tapering, the hair full and flowing. Now, *why* are these proportions and forms *beautiful?* Nor is this all; but let it suffice, for the moment, that none of these writers attempted to show *why* these forms were beautiful and none other. Mr. Haydon, Sir Charles Bell, and others, endeavour to adapt our notions of beauty to circumstances altogether external and extraneous; sometimes they said it was "the contrast with the brute form which made us think them beautiful;" at other times it was the intellectual character. The notions of Sir C. Bell and of Mr. Haydon on all these points, we shall find so contradictory as to be scarcely worth a serious refutation; and my noticing them so particularly, is merely in compliment to the genius and ability which these distinguished artists clearly possessed.

The very beautiful and delightful arts of Statuary and of Design or Painting, are unquestionably of the highest antiquity. The oldest of all records in the world, the Tombs of the Egyptian Thebes and Memphis, show that painting was at least a sister art with statuary when these seemingly eternal monuments were erected; coeval, perhaps, with the Sphinx and the Memnon—coeval probably with the Pyramids. The antiquity, however, of these noble arts is not, I think, in itself a circumstance so wonderful—I had almost said incomprehensible—as the perfection, the all but divine perfection, to which they were suddenly carried; not, however, by the Egyptian race, or Coptic, with whom art, the beautiful and wonderful, seems suddenly to have become stationary; but by their copyists, the Greeks, for such we are almost bound to consider them. Indeed I have no doubt that the Greeks were allied to the Copts, by ties of consanguinity closer than are generally admitted or supposed. Of Egyptian art I shall speak presently, and next of the Greek. The Romans also were artists, and so also are the English and French; but what they have done, or may do, does not seem to me particularly connected with high art. Noble statues they no doubt chiselled, and exquisite paintings they sketched and finished; compositions of surprising grandeur they conceived and carried through; still this does not seem to alter my position, namely, that the Egyptians and Greeks commenced and finished art. What Euclid did to geometry, Homer to poetry, so did the great unknown who built the Thebian temple to architecture; and those who chiselled the Venus, and the Mars, and the Apollo, and the Laocoon, perfected statuary—placing before human sight figures of such surpassing beauty, that, for at least twenty centuries, men of cultivated minds and exquisite taste have supposed them not to represent the human figure as found in nature, but an ideal form—a conception of the artist. Inconceivable, that the grandest conceptions of earth-born man could surpass those of his Creator!

But before entering deeply on this matter, I shall venture a single remark relative to the comparative ages of Egyptian and Greek antique art.

Herodotus was amongst the earliest of writers who accused the Greeks of having borrowed everything from the Egyptians—of being to them what the Romans were to the Greeks, and also to the Romans. This may be true or not; it may be wholly true, wholly false—partially true, partially false. We know not exactly a single ancient date strictly so called. Nothing of the age of the Pyramids, the Sphinx, the Niobe, any more than of the Townsend marbles. Thus is it doubtful in what the Greeks imitated the Egyptians. A Greek era preceded the era of Phydias, whose history has been lost: "multi ante Agamemnona fortes viri," is a well-known truth. The Homeric ballad itself is said to have been written in Egypt, and with some show of probability. It is strange, indeed, that the sublimest of all poems, the grandest of all architectural achievements, and the most finished representation of the human form, possessing beauties which men have not yet explained satisfactorily, should have been executed by persons and in an era absolutely unknown!

I shall divide this discussion into three parts: in the first, I shall consider the human figure; in the second, the representation of the human figure by the Egyptians; in the third, the same as attempted by the Greeks. The efforts of Rome, ancient and modern, do not seem to me to merit a separate chapter. Of modern art let me speak with all gentleness and forbearance; the greater portion is, of course, below all

notice, speaking with exclusive reference to high art as displayed in sculpture alone. Good imitations, seemingly constituting high art, we have, and will continue to have, no doubt, in abundance, the productions of clever men, from Michael Angelo to Canova, and from Titian to Reynolds; but that is all. Nature may be copied to all eternity, but until something more beautiful than nature's most finished production appear on the earth, the antique statue can never be surpassed. The proofs of the correctness of these assertions will, I trust, be made apparent from what will be advanced in this and succeeding papers. In the meantime I shall proceed to inquire into the source of our ideas of beauty with respect to the human figure.

That all Nature's works are beautiful, is a familiar and usual mode of expressing a great truth, arrived at by a process of reasoning quite separate and distinct from all human instincts. It is a philosophical truth of a high order, and has nothing to do with man acting from his unerring instincts. These declare to him in another language, that certain objects alone are beautiful as forms; certain sounds alone are musical; certain actions alone are graceful; and that these ideas, composing an intrinsic part of the correctly-formed mind, have nothing to do with fanciful theories based on human reasoning, such as the "Theory of the Curve," and the "Theory of the Association of Ideas."

As it is not by any process of reasoning that we decide on the beautiful in art or nature, however much it may afterwards aid us in investigating, with more or less probability, the grounds of our belief; so reasoning employed as a substitute for, or in the absence of, a sound instinctive feeling, always has, and ever will mislead the mind from the true path of observation; and the only legitimate use of the reasoning powers in such an investigation, is not to declare what is really beautiful in human form, but to show in what this differs from that not so esteemed; and to trace to some great law or laws regulating our instincts, the source and cause of these ideas.

With this view I subdivide the human figure into various sections or parts. The draped and naked figures offer a mechanical, one might almost say an artistic, division of the human figure, into head, hands, and feet, these being the sections exposed, and trunk and limbs, as the parts clothed. But sculpture, which alone perhaps constitutes high art, requires us to consider the entire figure as one; yet nature does not always view it as such, adapting very frequently to the noblest torso which the English figure so often displays, most pitiable lower extremities, falling off in every sense beneath the dignity of human nature. Never was a nobler trunk seen than was exhibited by the sable Congo Black, Molyneux; but the shanks were negrine and misshapen—laughable, in fact, though made by nature. Instinct, unerring instinct, tells us that the legs and feet of negroes are almost a burlesque on humanity; but reason forbids us to mock at any of the Creator's works. Noble, beautiful feet and hands may be seen daily on an ill-made torso; there is no rule in this respect. And faces which are often called divine, may be seen surmounted by brains scarcely elevating the individual above the lower animals; or a fine torso attached to trunks and limbs, which any one, no matter to what extent he may have warped his unerring instinct by theories about the "association of ideas," or "the adaptation of wisdom and design," must still, when forced to it, unless defending himself by a sophistry against his own belief, admit at last to be anything but beautiful.

Though attaching no importance, then, to such subdivisions of the frame, I may yet consider the figure under the following heads:—1. The Hands. 2. The Feet. 3. The Limbs. 4. The Trunk. 5. The Head and Face.

Thus I reserve for the last the most difficult subject—the human face, which to beauty of form adds the mystery of expression; and not only is this expression natural, but there is an artificial expression, the result of habitual passion or policy, of which our great dramatist speaks when he says:

> "God has given them one face, and
> They make themselves another."

The draped figure occurs so universally over the globe with all races of men, civilised and uncivilised, as to give rise to an idea, seemingly a very natural one, that the head, hands, and feet were the only parts of the body which nature intended should be exposed. Even the Bosjenam wears clothing of some sort, seemingly, however, for warmth; uncivilised races clothe, in general, merely the trunk, leaving the head and neck, the arms and limbs, naked. The Romans merely clothed the trunk, concealing the lower limbs in the ample folds of the toga; sandals displayed the whole outline of the foot, which the modern shoe and boot conceal. Dress at last usurps nearly the whole surface. But all this is, of course, entirely artificial; nature made the whole body *visible*, that which she made *visible* she occasionally makes transcendently beautiful; she made nothing beautiful but "*the visible*," every thing else is frightful to the untaught eye. "The visible" alone she decorated; that alone she intended should be seen by the million; with that alone she associated or linked eternally all our notions of the beautiful; for the display of what she concealed she has implanted an innate dislike, a secret horror, to be overcome, it is true, by the scientific inquirer, but still requiring an effort; when known, it also is found to be admirable and wonderful, but never beautiful. To call a skeleton beautiful is a mockery, an abuse of terms; nay, to such a length has nature carried this, her apparent system, that if, in the delineation of the visible, the artist displays, so as to be perceptibly felt by the mind of the observer, what she intended should neither be seen nor understood to be present, that instant does his figure, statue, or drawing cease to be beautiful. This proposition, with others on which it is here attempted to found a theory of Beauty of Form, which shall apply to and include all mankind, as well as the antique Greek statue, I shall now proceed to illustrate by an examination of the Hand, the Foot, the Limbs, the Trunk, and last of all, as presenting the greatest difficulties, the Human Head.

THE HUMAN HAND.

The human hand, like every other portion of the frame, may possess a form universally admitted to be beautiful, such as the hand of many antique *female statues.* Woman's hand alone is beautiful, and yet not every female hand, but only those whom nature has chosen to perfect. The male hand may also be beautiful when formed like the female; but then it ceases to be a male hand, properly speaking. A well-formed male hand should be broad, strong, firm, and square; its qualities are those of strength and agility. The term beautiful in no sense applies to it—cannot at all be applied to it: the mind, in fact, sees no beauty in it. It is formed for action, for strength, and for dexterity; these are qualities which are never associated in the mind with the forms termed beautiful. On the other side, look at the hand of the antique female statue, and at the living hand when *perfectly female;* the beauty of such a hand, like beauty wherever placed, lies entirely on the surface. Its leading features may be summed up as follows:—they have a reference to those instinctive perceptions which regulate the human mind in the discovery of that which is intrinsically beautiful, and are directly opposed to those principles on which anatomists, physiologists, and metaphysicians have based their theories of beauty.

1st, To decide on the perfection of the hand as a "beautiful object," it is necessary to see it in connection with the wrist and a portion of the fore-arm, but more especially the wrist. This latter part must be rounded, full, polished; smooth; no *prominent* veins, no stringy tendons, no wrinkles, no projecting bones, which above all things are abhorred; sinews and starting veins are bad enough, but those are still worse. Much has been said about making visible or concealing the extremity of the ulna, the smaller head, as it is called, and styloid process of the ulna, the bare mention of which naturally-concealed parts banishes from the acute mind all ideas of beauty—beauty! the most timid, the easiest frightened of all our instinctive feelings. Now, the less prominent these said portions of the ulna are made the better; they had better not be shown at all: in some positions of the hand

they are invisible: in no effort of the beautifully-formed hand does this bone ever become distinctly prominent; if represented at all, it must be by management of light and shade, giving to it the most delicate roundness possible. Represent it as the end of a bone; bring out its anatomical character; let the mind discover that a skeleton lies under that fair skin, and every idea of beauty flies from the mind with the speed of lightning. Here, then, I venture to announce the first principle of beauty, which is a surface, or external envelope, concealing not only from the eye, but from the mind's eye, the slightest form suggestive of an internal structure—a skeleton, a sinew, or a muscle. This magic surface, which conceals from our view all that nature intended should be concealed, is not mere skin; nor will any skin suffice. It must possess the following qualities—and here I beg to announce the second principle on which abstract undeniable beauty of form depends:—

2nd, The integument enveloping the wrist and hand must be that of youth—the youth of 15 or 16; oftener found, however, at 4 or 6. Either sex will sometimes suffice in this respect, but woman above all. Youth alone is beautiful, or rather an appearance of youth is absolutely essential to the beautiful. The slightest approach of age is noticed by the observing eye, as the nice ear detects a discordant note. Of all the qualities on which beauty depends, this is the most essential, "the semblance of youth;" nothing is really admired, nothing loved, but the young, or that which "*looks like youth.*" In the full bloom of the young woman—the first bloom, in fact, which is sometimes so fleeting as to endure but a few months in all its vigour, leaving, however, many traces occasionally enduring for many years—a soft cushion or layer of elastic fat forms the inner layer of the integuments, nearly over the whole body. It is the presence of this layer of adipose tissue which contributes so greatly to give that universal beauty to children. This layer woman often retains on most parts of the body until old age; man loses it early, say at 18 or 19, and he seldom holds it beyond that age; but as regards the hands, and especially the feet, it most frequently, in this country, all but disappears at 8 or 9 in both sexes, which takes from the form all pretensions to the beautiful. By means of this layer or cushion, every muscular interstice is filled up, the smoothness of the outer integument is maintained, all angular projections are concealed—projections which reveal the interior osseous frame of some structures, not only frightful to look at, but associated in our minds with all that is fading, frail, and mortal. By means of this cushion, which disappears from the feet, hands, and wrists of the coarsely formed, so early sometimes as seven or eight years of age, the sinews or tendons are concealed, the very sight of which, and even the suspicion of the existence of which, give rise to ideas so adverse to the beautiful. The integumentary veins are naturally small, and so long as the larger veins, which lie concealed in this layer of fat, but more towards its inner than outer surface, are sufficiently covered by it; they are, of course, invisible, as nature intended them to be; but let this fat only disappear, and mark what follows: wrinkles and loose folds of skin, large veins, strong sinews, projecting points of bones. Now, why are these disliked by the mind?—why do their coming to the surface destroy all the charms of the individual?—why are those parts which the anatomist is pleased to investigate and the philosophic inquirer to contemplate, unpleasing, nay, abhorrent to the mind? Do they indicate weakness? Certainly not in the male hand, nor in any healthy hand. Do they indicate a want of conformity to the purposes and uses of the hand, as Sir Charles Bell would say? The very reverse; they are often proofs of great strength and dexterity. Why are they not beautiful? Simply because they reveal that which nature intended should be concealed; which she has concealed in her most exquisite forms, and moreover, are mysteriously connected in the mind with that condition the most adverse of all to beauty, viz., the approach of age, age and decrepitude, age and decay, decay the most abhorred, the most disliked of all human events, saving death, when all form speedily ceases, and the figure, which had lost every trace of beauty (the term cannot even be mentioned in connection with the idea of age), sinks into nothing, assuming first those forms of extreme decrepitude and decay, distressing to behold, from which all minds naturally revolt; to honour and respect which, requires the highest effort of *reasoning* (far opposed to all our instinctive feelings), and the special command of our Creator. Youth, and the semblance of youth, alone is beautiful—youth, imbued with certain forms, or rather youth combined with, and also indicated by, certain forms; for youth may be present, and yet the person or part may be far from beautiful, if it err or be contrary to certain proportions, of which I shall speak presently. Or, if it so deviate from the form which youth ought to have, what our instinct tells us it ought to have—then, no matter how young the person may be, the appearance of the part suggests to the mind the advance of age, and were he or she only six years old, the person would cease to be beautiful. Should any one doubt this, let him look at the naked feet of thousands who walk daily the streets of Scottish towns, and observe how early the *senile foot* appears! It may be seen in very many of these at ten years of age—at six, nay at four. But no one pretends to say that such feet are handsome, however young the person be; a broad and flat sole, projecting bones at several points, square forms for round and waving, deep hollows where none should be, and stringy, coarse projecting tendons, where the mind looks for smooth and polished surfaces. The question is not, are these handsome feet or not? nobody will venture to call them handsome, much less beautiful; the question is, why does the mind deny that they are handsome? The answer is this: first, the surface reveals that which nature intended should be concealed; second, these forms suggest the unpleasing, abhorred idea of age; third, they err in proportions and symmetry. This last we shall next consider with reference to the human hand.

3rd, The *qualities* of youth, and of the concealment of that which nature intended should not be revealed, are, in the perfectly beautiful hand of woman, extended to the extremities of the fingers. Nowhere can you detect joints, angles, or processes, as they are called; nowhere sinews, arteries, or veins; nowhere are ligaments to be observed. Lines and grooves there are, no doubt, not deep but graceful; in the palm of the hand they give rise partly to the lights and shadows; the anatomist himself cannot detect with the eye the exact situation of the joints; he sometimes experiences a difficulty in finding them even when amputating the fingers. In the palm of the hand we have the themar and hypothenar eminences, or projecting fleshy masses, connected with the thumb and little finger, which in the fine hand are full, rounded, and softened; no flatness, no hardness must be visible here; no sinewy, lanky surface, where the mind expects to find rounded surfaces. These eminences are singularly beautiful, even in mere form; the shadow they cast over the palm of the hand stamps their character. And even the fingers must taper gradually to correspond with the arm, which tapers uniformly from the shoulder; not too long or short, but proportioned to the hand; the hand proportioned to the wrist, projecting but little, if at all, beyond it; there must, in fact, be no short projections, no angles from the shoulder downwards, all must taper generally, and rise or fall in gentle curves. A straight line on the inner side of the hand would destroy its appearance, however beautifully formed otherwise; so also would perfectly straight fingers. Such forms suggest age; they further suggest ideas connected with internal structure; they form *useful hands*, hands which bring lofty and sweet tones from the piano and harp; which guide safely the surgical knife; which skilfully perform all mechanical arts; to the *reasoning* mind they are *beautiful*, being associated with what is useful; but by that mind which alone understands and decides on real beauty—abstract beauty—viz., the instinctive mind, these forms are declared not to be *beautiful*. What reason admires, instinct regards not; instinct has no associations, no theories, no logical conclusions. It is *reason*, or rather a misapplication of the reasoning powers, which has misled the artist, the anatomist, the metaphysician, on all such points. Whilst they in vain, as I believe, looked for the sources of our ideas of the beauti-

ful in some silly fancies, such as curved lines, fitness of parts, adaptation of structure to an end, proofs of wisdom, contrivance, and design; the correctly-constituted mind, the mind qualified to judge of the beautiful, independently of all logic, simply said such and such forms are beautiful, such and such are unpleasing, such are deformed, such are frightful. Analyse the expression of these correct instincts, and it amounts to this: the visible alone is beautiful, the visible alone has been decorated by nature, the visible alone clothed in the attributes of youth. What does the transcendently beautiful line of the back of the Venus indicate?—youth. What the sloping shoulders without a furrow, without a projecting angle; the tapering limbs; the softly rounded feet and hands?—simply youth, infantile youth, and the absence of every, the remotest symptom of age or decay. To this the mind instinctively looks—no reasoning can divert it from the forward look—ever onwards towards futurity. The returning spring, the bursting verdure, the opening rose, the budding leaves, the freshness of the forest at the approach of summer, all indicate youth. It is not, then, altogether that such and such a form, merely as a form, pleases or displeases, but simply as it coincides with that first great principle of our nature, viz., to love those forms which most clearly belong to youth in its most perfect state. To say that this depends on any association of ideas, is to trace that to reason and habit which belongs to instinct —to trace to extrinsic circumstances that which depends on intrinsic sources. The next step would be, to declare the music of Mozart and Rossini beautiful merely as associated with Italy, or with our recollections of the Opera-house; and that the noisy, ranting sea-songs of Britain, the Rule Britannias and the Duke of York's March, are quite equal to the magic strains of Beethoven and Bellini, seeing that they delight the English audience, and are yelled and vociferated by a thousand voices, keeping no time and expressing no music, but only appreciated as giving utterance to national sentiments, evoking bacchanalian associations, or otherwise touching some chord of the heart which does not vibrate to the beautiful.

Before applying the principles just laid down to those statues of antiquity, which, representing male figures, are yet of extraordinary beauty, and thus explaining what at first sight may seem contradictory, I shall consider the form of the antique foot and ankle. Symmetry, or a perfect resemblance to each other, though equally essential in the hands and feet to constitute perfection, does not, for obvious reasons, take the eye so readily in the hands as in the feet. I shall consider, then, in what consists the perfection of the foot: this leads naturally to the consideration of the arms and limbs, in speaking of which the applications to the male antique figure may be more appropriately made.

THE ANTIQUE FOOT.

The foot of the Venus of Medici, and not it alone, but the feet of the other antique female statues, have been admitted by all the world to be perfect and unsurpassable. Artists acknowledge the great difficulty they experience in drawing the human hands and feet; the sculptor, no doubt, meets with equal difficulty in his department of art. Many artists cannot draw them at all; this is matter of daily observation. A distinguished artist once told me, that in order to be able to draw the human hand well, he had sketched the *skeleton* of the hand many hundred times. We shall presently see that this was not the way to acquire a knowledge of the *form* of the perfect hand or foot—the female hand or foot, which is all perfection when finely formed. The foot of the antique Venus is perfect; now, why is this foot so perfect? Of a thousand bare feet walking the streets of Glasgow, you will not find even one tolerably well made; perfection or beauty is out of the question. I know what a certain class of pseudo-philosophers will say is the cause of this deficiency in beauty; they will ascribe it to the walking barefoot: and had these persons worn shoes, the same would-be physiologists would have blamed the shoes! The miserable shanks of the burly big-shouldered Saxon Englishman, Sir Charles Bell ascribed to his wearing clogs, or heavy shoes, when young! But the French wear clogs, and they have a stout calf to the leg. Physiology of this kind is scarcely worth adverting to.

To ascertain why all of good and correct taste see in the foot of the antique Venus the perfection of nature and beauty, not to be excelled, we have only to apply the same principles already applied to the hand, and the result is as follows:—

The foot of the Venus is exquisitely beautiful, because—1st, It retains the *form of youth;* the infantile form prior to any, even the slightest, alteration. Look at the foot of the beautiful and well-formed infant of 2, 3, or 4 years of age—it has the foot of the antique Venus in miniature.

2d, It is proportional and symmetrical; proportionally to the height, considerably less than the male, in accordance with the whole delicacy of the form, the gentleness of her nature, the qualities of her mind, and, by contrast, the qualities of man's.

3rd, The second toe is the longest; the first is somewhat apart; the nails are small and regular; there are no sharp angles or visible projections of bones. The ankles are round and polished; the heel is small; the tendon achillis is invisible.

4th, The visible alone is represented, taking care that nothing may reveal the deep structures, the structures nature intended should not be seen. To render a foot repulsive to be seen, the artist has only to show a prominent, stringy projecting tendon achillis. Who will handle such a foot? Who will look now at it? In Britain, at least, (I know not how it may be in other countries,) the tendency to deformed feet, or at least to feet deviating from the beautiful, commences often as early as 3 or 4 years, and it may be seen even younger.

Look at the feet of the passing crowd of females in Ireland, and mark how each or all show such a deviation as to leave no doubt in the mind of the absence of the enviable quality of the foot. How rare is perfection of form! No wonder that the whole world admires, and in former times almost adored, transcendent beauty! Look at the feet of the mendicants, even of the youngest; already may be seen in some the whole anatomy of the foot, made palpable and visible by the early disappearance of the subcutaneous cellular cushion of fat. The outline of the skeleton is discovered, and as soon as visible, puts to flight all ideas of beauty; the back of the foot, instead of swelling beautifully and gradually from the base of the toes to the instep, becomes suddenly flat, and soon curved the opposite way; or the toes are plaited, or the great toe is the longest, the foot is unshapely, broad, and square; the extremity of the metatarsal bone of the great toe projects in a frightful and unseemly way, or one foot is larger than the other, or the left malleolus is lower than the right, and almost meets the ground; or the tendon achillis projects, exposing two large hollows on each side, and the ankles projecting as if they were about to cut the skin; or all the veins are seen, or the hollow of the foot is so deep as to make the foot look as if clubbed. These, and endless other circumstances, exposing either the anatomy, or imitating prematurely the *forms of age,* drive from the mind every idea of beauty in such a foot; and should any one be doubtful for an instant of the correctness of his instinct, let him compare such a foot with the foot of the Venus.

The following observations on one of the more remarkable deviations from beauty in the form of the foot, were written some years ago; they illustrate the preceding remarks, and offer some points of interest to the general reader:—

REMARKS ON A COMMON DEFORMITY OF THE FOOT.

The human foot, like every other part of the body, is liable not merely to great variety in form or shape, still confined within natural bounds and a strictly human form, but also to a number of deformities, congenital and acquired. I shall speak first of the natural form of the foot, and of the proportionate and strictly beautiful foot, and of the probable sources of our ideas of the *beautiful* in respect to the human foot. The first remarkable circumstance in regard to the human

foot, whether male or female, is that in childhood, (I mean before the fourth year or thereabout), the feet are frequently well-formed, and possess that form which, should it persist in the grown-up woman, all men at once declare to be beautiful. There are, of course, exceptions, but speaking of the young foot generally, whether male or female, I should feel disposed to describe it as being seemingly short, compared with the stature of the child: its inner margin straight, but more generally somewhat arched inwards; the great toe either placed on the same plane with the inner margin of the foot, or somewhat arched inwards, and slightly detached from the second, leaving an obvious space between them; the second toe longer than the first; all the surfaces smooth, and as if chiselled in marble; one gentle elevation, somewhat arched, carries the back of the foot from the toes to the instep; everything is taper, soft, gently traced; neither sinews, nor veins, nor bones, are visible; the whole, in fact, is eminently beautiful, and in keeping with all those pleasing and graceful forms which render the child an object of gentle attraction even to the sternest natures of mankind. After this period, sooner or later, the form and proportions of the feet begin to alter; in the boy they soon take on a masculine form and male proportions; the tendon achilles becomes prominent and strongly defined. The foot acquires a length in the grown man equal to a sixth of the whole length of the individual; in the full grown woman about a seventh and a half; that is, woman's foot is absolutely shorter, comparing height for height, than the male foot. So that if both individuals measure 66 inches in absolute height, then the male foot will, and ought to, measure eleven inches, or a sixth of the total length: I say ought, for if less, even by half an inch, an air of effeminacy and insecurity is given to the whole figure. On the other hand, the female foot of a person 66 inches in total height will be found generally to measure somewhat less than nine inches; and if more, it gives to the whole an unpleasing masculine character, a character of strength, solidity, and firmness, unsuited and unexpected in female form. But the changes which the human foot undergoes are not confined to proportions merely; the more remarkable regard the intrinsic shape and character of the entire foot. The female foot, when perfect, retains, and ought to retain, much of the infantile or childish form; its straight inner line, and its freedom from angular proportions; but above all, as I have already said, its infantile character, from which the male foot deviates so widely; and this it is which preserves for the finely formed female foot, that of the Venus for example, the title of *beautiful*, to which the finest formed male foot has no pretensions whatever; it is the retaining of that infantile character, associated in our minds with youth and health, grace, simplicity, and truth, loveliness and confiding helplessness of the person, which makes her foot so perfectly beautiful. It is proper to observe here, that the foot of the very young child or infant differs from that of the child of three, four, or six years of age; it is not so pleasingly formed, retaining something of the fœtal form (which is never pleasing), an inner line too much curved, a large toe longer and stronger in proportion than what taste reckons comely, and too widely separated from the second; the foot, like all other parts of the body, ungergoing phases or changes from, and even before, birth until its maturity and ultimate decay. In a word, the fœtal forms are unpleasing; the infantile on the contrary are beautiful.

If we turn now to contemplate the same instrument in the adult, whether male or female, whose proportions may not be so favoured, we frequently find that a congenital deformity, or at least a tendency to deformity, soon, at least in some, begins to show itself; the deformity to which I allude is that peculiar dislocation of the great toe, or change in its direction from a straight line with the inner plane of the foot, (or even arched inwards), as it once was, to that of an angle, more or less acute, with the metatarsal bone supporting it, until at last it produces a plaiting, as it is called, of the toes, the large toe passing either under or over the second. This plaiting leaves exposed the distal, large, rounded end of the metatarsal bone, which some surgeons mistake for a tumor, and treat as such, calling it a bunion; the internal lateral ligaments give way: they spread out, in fact, become lacerated, and reduced slowly, but surely, to mere shreds; occasionally a small bursa or two forms just over these ligaments; at last, the bone appears, which the surgeon next attacks as an exostosis and morbid growth, the anatomist knowing all the time that the whole of this surgical view is a delusion, an inconceivable error; that the metatarsal bone is, in fact, in its place, and that nothing whatever has happened excepting a slow but constantly increasing change in the direction of the great toes, merely producing a plaiting of the toes, a stretching of the lateral ligaments, much uneasiness, and positive pain; and, should the dislocation proceed so far as to expose the joint, it produces much real distress and suffering. In respect to the internal condition of the joint I may here briefly remark, that the cartilages of incrustation disappear from the surface of the bones, which become smooth and not unfrequently take on an ivory polish.

Here, then, is one cause for the destruction of the cartilages of the joints, but seemingly not abrasion; these cartilages have disappeared, not by too much friction exercised on a part, but rather by too little, a cause just as effectual in causing absorption or disappearance of cartilage from the extremity of bones, as the opposite; it may indeed be laid down as an axiom in regard to the diarthrodeal cartilages, that they are affected, more or less, by every change of the joint, whether the change refer to an alteration of the mode of leverage, or to the mere exercise of the individual parts.

The dislocation outwards of the great toe I have just described, sometimes in one foot, sometimes in both, is one of the most common deformities met with in the human foot.

A Surgical Remark applicable also to other Joints.

I have never seen it in any savage race, but so far as I can judge, (and in Scotland opportunities for observing the naked foot at all ages are by no means unfrequent), the deformity is quite common amongst all ranks and every age, with the exception of the very young. It seems to me to arise from a congenital predisposition; everything I have seen, everything I have observed, and all the dissections I have made, are, in my mind, subversive of the theory of Mr Key, and others, who maintain that it may be traced to tight and short shoes, to too much standing erect, aided by age and corpulency. I repeat I have never met with a single observation confirmatory of such a theory. I have seen the deformity at ten, twelve, fifteen, and in the mere stripling and girl who scarcely ever had a shoe on his or her foot; the extremely corpulent and active, I have observed, at the age of forty, fifty, and sixty, with feet nearly as well formed as the Venus. I have heard of many other theories equally inadmissible with the one just mentioned, in respect to the cause of this so frequent deformity; but one of the last, though certainly not the least ingenious, was one propounded to me by an old six-feet high admiral: he had suffered much from this dislocation outwards of the great toe in both feet, which misfortune he was not disposed to ascribe to any original predisposition, but solely to his dancing-master, and to the absurd practice of civilized well-bred nations walking with their toes turned outwards, pointing out to me, with much confidence in his theory, that the savage, who had no dancing-master, never had this complaint, but had at all times a well-formed foot. How ingenious are the theories of the non-professional, but at the same time how totally destitute, like many of our medical ones, of even the slightest foundation in truth.

It has often occurred to me that this deformity of the foot is more common in the Saxon than in the Celtic race, and occurs oftenest in large, raw-boned, ill-proportioned tall persons; nature seemingly leaving, in such persons, the extremities unfinished. I have already stated that the disposition to it may, in some, be seen very early; at ten, twelve, or fifteen, increasing with years, never improving, and seemingly incurable. All contrivances I have as yet seen, devised for restoring the great toe to its right direction, have entirely failed. The tendon of the extensor longus, and its muscle, after a time,

aid in increasing the evil, by drawing the toe still more forcibly outwards; so that in addition to the wedge which some have proposed placing between the first and second toes, to counteract the tendency to displacement and consecutive partial dislocation, (which are, in fact, the essence of the disease), this tendon will require to be divided. My bootmaker lately mentioned to me the idea of an ingenious gentleman who had, in returning overland from India, visited Egypt, and being much struck with the form of the foot of the Egyptian mummy, and particularly with the remarkable straightness of its inner line and great toe, in which no obliquity outwards could be discovered, adopted for the nonce the very pretty theory that all this was owing to the form of the Egyptian sandal; and that our crooked feet, and plaited great toes especially, could be ascribed to nothing else but to the pointed narrow form of the European shoes! Of course it had never occurred to him that something might be due to the race of men to whom the feet belonged; that the Saxon and the Coptic races might, after all, not be identical; that, as they differed remarkably in physiognomy, colour, shape, intellectual and physical qualities, so they might also differ in respect to the form of the foot. These were points which perhaps had never occurred to him; so he ordered his bootmaker to make all his boots and shoes on the model of the Egyptian sandal given him for that purpose, and taken originally from the foot of a primitive copt. I sincerely trust that the experiment may succeed; in the meantime I must retain my doubts until he satisfies me of the identity of the races.

In thus opposing the theory of Mr Key, in regard to the causes producing this deformity of the human foot, justice to myself compels me to state that, before doing so, I have endeavoured to obtain information in every way. Being aware that nearly all "the trade" (I mean of boot and shoe-makers), entertained the same or similar views as Mr Key. I felt that there were two of the highest authorities opposed to me: the practical surgeon and skilful observer of great eminence, and the practical workman. But now that, in Scotland and Ireland, I have looked attentively at hundreds and hundreds of naked feet, in young and old, I feel confident in the correctness of my views. One of the very last observations, as showing the congenital nature of the deformity, or rather of the tendency which leads to it, occurred to me while waiting for the railway train in Forfarshire. A girl, apparently about thirteen or fourteen years of age, stood by me: she was a light figure, and by no means ill-proportioned, or in any way deformed; but on looking at the feet, which, as usual, were naked, I observed a remarkable plaiting of the great toe, with the usual bulging out of the distal end of the metatarsal bone. The foot seemed a little shorter than the other, which was otherwise well enough made, but showed that deep hollow between the toe and heel so frequent in the large ill-made feet of many adult males and females, which, in her case, was more strongly marked than usual. But that which struck me most forcibly was, that her mother, who stood by her, had precisely the same deformity in the opposite foot.

Thus all I have seen during the last twenty years convinces me that the deformity in question is not caused, generally at least, by the use of tight shoes (theory of Mr Key, and of all shoemakers), nor by the instructions of the dancing master directing us to turn our toes outwards in walking (theory of the Admiral I have referred to), nor by ill made shoes generally (theory of the gentleman who had visited Egypt): but arises mainly, if not solely, from a congenital tendency or disposition in the foot of some persons to assume this form; and that—

First, it occurs at nearly all ages, often at five or six.

Secondly, in males and females indiscriminately, whether heavy or light made, and whether they have worn shoes or not.

Thirdly, it may be confined to one foot, or found on both.

Fourthly, it leads to an atrophy or disappearance of the cartilages of incrustation, and of the synovial membrane; and as this cannot be by pressure, nor inflammation, nor apparently by ulceration, it must originate in the altered form of the joint, and the non-use of the cartilages themselves

Before returning from this digression on a pathological condition of the human foot, I shall take the liberty of adding a few remarks in respect to a point or two which, to me, seems not well understood. It is well known that a short shoe or boot, although always unpleasant, may be put up with so long as the person remains seated or laying down; but let him walk about, then the distress becomes insupportable with a rapidity dependant on the shortness of the "chaussure." Now, how is this? Anatomy explains it perfectly. The arch of the foot is not a solid osseous arch, unyielding and inelastic; but, on the contrary, possesses within itself the power of elongating itself (when the weight of the body is on the arch), by means of the calceo-scaphoid ligament. The elongation may amount to nearly half an inch. The elongation is due to the elasticity of this ligament. Now, if the shoe merely fit the foot *at rest*, it cannot fit it *in action;* for under the weight of the body, the arch, by means of the ligaments, will lengthen about half an inch: this it is which so speedily renders the short shoe unsupportable.

THE STEAM ENGINE.

CHAPTER III.

The following is the eloquent delineation of the character of Watt, by Lord Jeffrey, alluded to in last chapter:—

"Independently of his great attainments in mechanics, Mr. Watt was an extraordinary, and in some respects a wonderful man. Perhaps no individual in his age possessed so much and such varied information, had read so much, or remembered what he had read so accurately and well. He had infinite quickness of apprehension, a prodigious memory, and a certain rectifying and methodising power of understanding, which extracted something precious out of all that was presented to it. His stores of miscellaneous knowledge were immense, and yet less astonishing than the command he had at all times over them. It seemed as if every subject that was casually started in conversation with him, had been that which he had been last occupied in studying and exhausting; such was the copiousness, the precision, and the admirable clearness of the information which he poured out upon it without effort or hesitation. Nor was this promptitude and compass of knowledge confined in any degree to the studies connected with his ordinary pursuits. That he should have been minutely and extensively skilled in chemistry and the arts, and in most of the branches of physical science, might, perhaps, have been conjectured; but it could not have been inferred from his usual occupations, and probably is not generally known, that he was curiously learned in many branches of antiquity, metaphysics, medicine, and etymology, and perfectly at home in all the details of architecture, music, and law. He was well acquainted, too, with most of the modern languages, and familiar with their most recent literature. Nor was it at all extraordinary to hear the great mechanician and engineer detailing and expounding, for hours together, the metaphysical theories of the German logicians, or criticising the measures *or the matter* of German poetry.

* * * * * * * * *

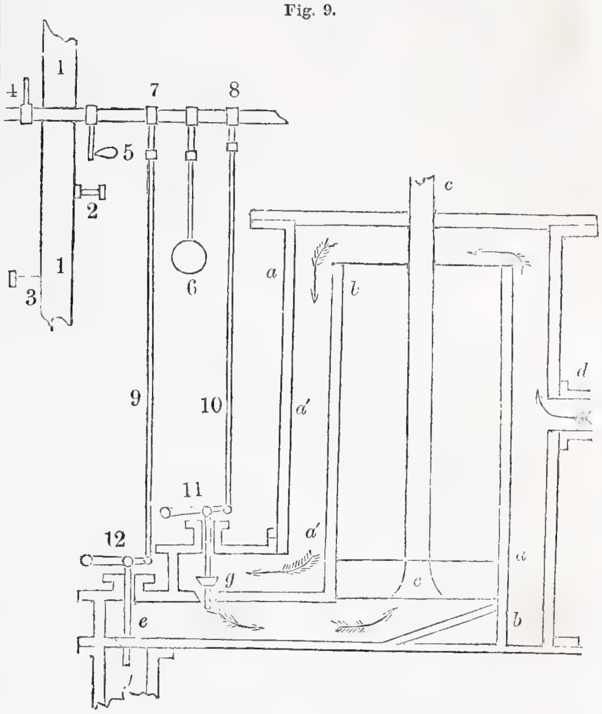
"It is needless to say that, with these vast resources, his conversation was at all times rich and instructive in no ordinary degree; but it was, if possible, still more pleasing than wise, and had all the charms of familiarity with all the substantial treasures of knowledge. No man could be more social in his spirit, less assuming or fastidious in his manners, or more kind and indulgent towards all who approached him. He rather liked to talk, at least in his latter years; but though he took a considerable share of the conversation, he rarely suggested the topics on which it was to turn, but readily and quietly took up whatever was presented by those around him; and astonished the idle and barren propounders of an ordinary theme, by the treasures which he drew from the mine they had unconsciously opened. He generally seemed, indeed, to have no choice or predilection for one subject of discourse rather than another; but allowed his mind, like a great cyclopædia, to be opened at

any letter his associates might choose to turn up, and only endeavoured to select from his inexhaustible stores, what might be best adapted to the taste of his present hearers. As to their capacity, he gave himself no trouble; and, indeed, such was his singular talent for making all things plain, clear, and intelligible, that scarcely any one could be aware of such a deficiency in his presence. His talk, too, though overflowing with information, had no resemblance to lecturing or solemn discoursing, but, on the contrary, was full of colloquial spirit and pleasantry. He had a certain quiet and grave humour which ran through most of his conversation, and a vein of temperate jocularity which gave infinite zest and effect to the condense and inexhaustible information which formed its main staple and characteristic. There was a little air of affected testiness, too, and a tone of pretended rebuke and contradiction, with which he used to address his younger friends, that was always felt by them as an endearing mark of his kindness and familiarity, and prized accordingly far beyond all the solemn compliments that ever proceeded from the lips of authority. His voice was deep and powerful, though he commonly spoke in a low and somewhat monotonous tone, which harmonized admirably with the weight and brevity of his observations, and set off to the greatest advantage the pleasant anecdotes which he delivered with the same grave brow, and the same calm smile playing soberly on his lips. There was nothing of effort, indeed, or impatience, any more than of pride or levity in his demeanour, and there was a finer expression of reposing strength and mild self-possession in his manner, than we ever recollect to have met with in any other person. He had in his character the utmost abhorrence for all sorts of forwardness, parade, and pretension; and, indeed, never failed to put all such imposture out of countenance by the manly plainness and honest intrepidity of his language and deportment. In his temper and disposition he was not only kind and affectionate, but generous and considerate of the feelings of all around him, and gave the most liberal assistance and encouragement to all young persons who showed any indications of talent, or applied to him for patronage or advice. His health, which was delicate from his youth upwards, seemed to become firmer as he advanced in years, and he preserved, up almost to the last moment of his existence, not only the full command of his extraordinary intellect, but all the alacrity of spirit, and the social gaiety which had illumed his happiest days. His friends in this part of the country never saw him more full of intellectual vigour and colloquial animation—never more delightful or more instructive, than in his last visit to Scotland in Autumn 1817. Indeed, it was after that time that he applied himself, with all the ardour of early life, to the invention of a machine for mechanically copying all sorts of sculpture and statuary; and distributed among his friends some of his earliest performances, as the productions of a young artist just entering on his eighty-third year!"

We now proceed to illustrate the principal features of the steam engine, as improved by Watt, first noticing the improvements effected in the cylinder.

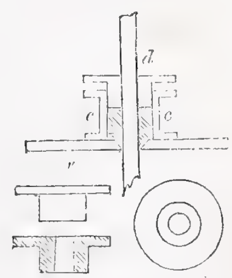
Fig. 9 shows the method of distributing the steam to the cylinder of a single-acting engine: *b b* is the steam cylinder, with the piston and piston-rod, *c c*; the cylinder is surrounded with a casing, *a a*, into which the steam was led from the boiler by the pipe, *d*. The steam had free access to the upper side of the piston, and was allowed to pass down the passage, *a′ a′*, through the valve, *e*, and by the passage, *f*, to the under side of the piston; *g*, the valve covering the passage leading to the condenser. The condenser, at this stage of the improvements, was formed of a series of copper cylinders or pipes of small diameter and of considerable length; these were placed in a cistern supplied with cold water. The condensed steam was withdrawn by a pump from the interior of these vessels. In place of having the piston open to the atmosphere, as in Newcomen's engines, Watt passed the piston-rod through what he termed a stuffing-box, made in a cover which was bolted down steam-tight on the cylinder. The piston-rod was kept steam-tight in the aperture by the stuffing-box; the arrangement of which is shown at fig. 10. A tube, with flanges at its ends, was fixed on the cylinder cover, of diameter considerably larger than that of the piston-rod and aperture in the cover through which it passed. A packing of hemp, well lubricated

Fig. 9.



with oil, was passed into the lower part of the cavity shown by the crossed lines; a box or gland, *d d*, shown separately at *d′*, was passed over the piston-rod, and forced into the space between the piston-rod and the interior of the box, *c c*, and secured in its position by bolts and nuts; the packing by this means was always firmly pressed round the piston-rod.

Fig. 10.

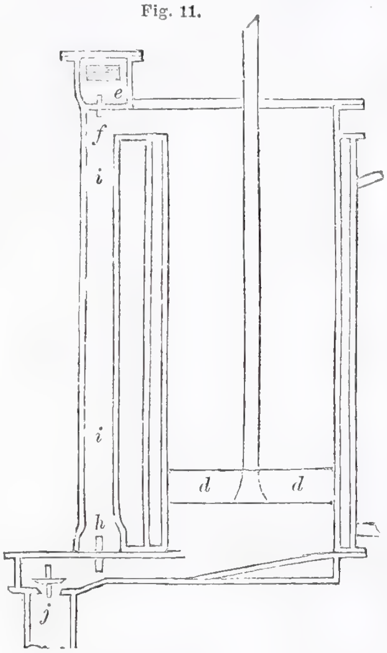


The method of working the engine, illustrated in fig. 9, was as follows:—Previous to starting, all the valves were opened, and the steam allowed to pass down to the condenser; by this means all air in the interior of the cylinder and the steam passages was got rid of. The valve, *g*, was then closed, and the valve, *e*, allowed to remain open; the steam from *d* was thus prevented from passing to the under side of the piston through the valve, *e*, while that which was already there passed through *f*, and the open valve, *e*, to the condenser. Into the vacuum formed in the under part of the cylinder, the piston was forced by the pressure of the steam, which had free access to its upper side; the end of the beam was thus pulled down, and the pump-rod of the mine was pulled up; a downward stroke was thus accomplished. The valve, *e*, leading to the condenser was then shut; the valve, *g* opened; and steam being thus admitted to press upon the under side of the piston, as well as its upper, an equilibrium of pressure was established, allowing the counterweight at the other end of the beam to act, and to pull up the piston to the top of the cylinder. The valve, *e*, was then opened, and *g* shut; this allowed the steam, as before, to rush from the under side of the piston to the condenser where a vacuum was formed, and the steam on the upper side of the piston forced it down, and thus the series of operations were continued as long as required.

The experience obtained from the working of this form led Watt to discard the system of condensing the steam in vessels

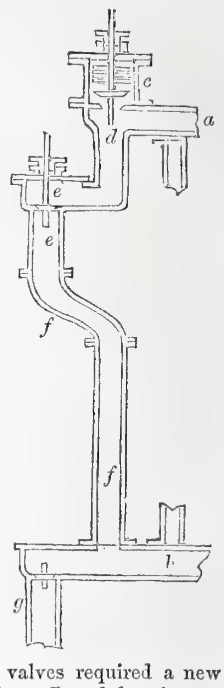
surrounded with water, and to adopt the plan of condensation by a jet of water projected into the interior of the condenser; he was also led to discard the outer casing, and to adopt a thin iron casing with only a space of an inch and a half between it and the cylinder, into which steam was introduced by a pipe leading from the boiler. This arrangement required a new method of distributing the steam to the cylinder; the details of which we show in fig. 11. Suppose the piston to be at the top of the cylinder, the steam-valve, *f*, is opened, admitting steam from the steam-pipe, *e*, to the upper side of the piston; the steam passes through the passage, *i i*, and the valve, *j*, termed the eduction valve, to the condenser. The piston, *d d*, is then pressed downwards to the bottom of the cylinder; the eduction valve, *j*, is next closed, along with the steam-valve, *f*; at the same time the valve *h* is opened, and the steam passes to the under side of the piston, when the equilibrium—hence the name equilibrium valve, *h*—is established between the upper and under sides, and the beam counterweight pulls the piston to the top of the cylinder.

Fig. 11.



In these methods of distribution of the steam, the steam was always acting on the *upper* side of the piston, while there was an alternate vacuum and steam pressure on the under side. In order to attain a more complete condensation, by allowing the steam a longer period to pass from the cylinder to the condenser, and thus give more time for the condensation to be effected, Watt introduced another method of "distribution," by which there was a perpetual vacuum below the piston, and alternate steam pressure and vacuum above it. The arrangement did not bring about the advantages anticipated, as the condensation was effected so instantaneously after the opening of the eduction valve, that no better condensation was effected by lengthening the time in which it passed from the cylinder to the condenser. As we are anxious, however, to give as full a detail of the various improvements introduced by Watt as possible—seeing the important lessons the young mechanic can obtain from their study—we deem it best to give an illustration of this, the third method adopted by the great inventor to distribute the steam to cylinders of single-acting engines. In fig. 12 we give a diagram of the arrangement: *a* is the upper port, leading to the upper side, and *b* the lower, leading to the under side of the piston; *c* is the steam pipe from the boiler; *d*, the steam or regulating valve; *e*, a valve, acting both as eduction and equilibrium; *f f g*, pipe leading to the condenser. Suppose the piston to be at the bottom of the cylinder, the steam valve, *d*, was closed, and the eduction valve, *e*, opened; the steam, passing from the upper side of the piston through the pipe, *f g*, to the condenser, a vacuum was formed above and below the piston, thus allowing the counterweight to pull up the piston to the top of the cylinder. During the whole of its ascent, the eduction valve, *e e*, was kept open, allowing longer time for the steam to pass to the condenser. The eduction valve was then closed, and the steam valve opened, when the steam, passing from *c* through the upper port, *a*, pressed the piston down. "Whatever advantage," says Mr. Bourne, "was thus realized, was to some extent only transferred from the working to the returning stroke, a heavier counterweight being necessary to redress any difference in the vacuum above and beneath the piston, which might arise from want of rapidity in the condensation. There was also a greater leakage of air at the stuffing-box, and around the cylinder cover, in this species of engine; and the rare steam or vapour remaining in the cylinder after the act of exhaustion, had its elasticity increased by the heat transmitted from the steam jacket, thereby opposing more resistance to the piston, and robbing the effective steam of a portion of its heat. These disadvantages, taken singly, are all trivial enough, and indeed the sum of them is of no very serious import. Yet, upon the whole, this species of engine appears to be somewhat inferior to engines of the ordinary kind, and it never, therefore, met with an extensive adoption."

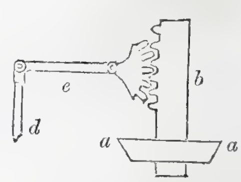
Fig. 12.



The method of working the valves introduced by Watt for the form of single-acting engine, illustrated in fig. 9, we have now to describe. Attached to the working beam was a plug-frame, 1, 1, fig. 9, having projecting pins, 2, 3. As the frame rose and fell, these pins struck alternately the levers, 4, 5, fixed to a horizontal shaft working in proper supports at each end. The shaft was thus made to turn round a portion of a revolution each time the lappets, 2, 3, struck the levers, 4, 5. A weight, 6, acted the part of the "tumbling bob" in Brighton's hand gear already described, and served to work the shaft equally. Attached to the shaft were two levers, 7, 8, connected by rods, 9, 10, with the ends of the levers, 11, 12, of the steam valve, *g*, and eduction valve, *e*. By the alternate rising and depression of the frame, 1, 1, these valves were opened at the proper time.

In the other forms of steam distribution, the arrangement of the valves required a new method of working them. This Watt effected by the arrangement shown in fig. 13. *a a*, the valve, the spindle being provided with a rack, into which the teeth of the quadrant, *c*, worked. This having a motion on its centre, through the agency of the levers, *d*, *e*, on *e* moving upwards the valve was closed, and *vice versa*.

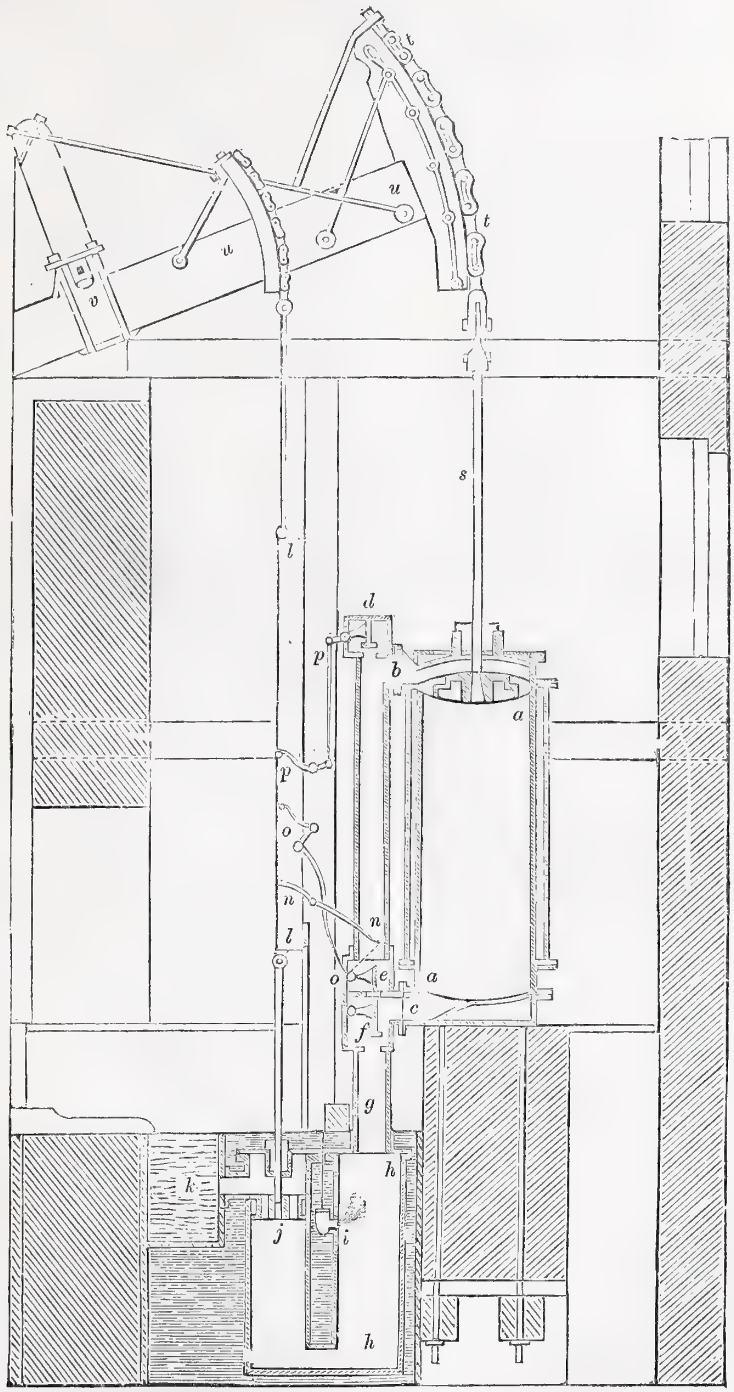
Fig. 13.



In fig. 14 we have given a view of the arrangements of a single-acting engine at this period, the operation of which we now proceed more particularly to describe. When the engine is at rest, the action of the counterweight of the beam tends to keep the piston at the top of the cylinder. Getting rid of the air below the piston is, therefore, the first thing to be attended to. To effect this, the attendant releases the catches of the handles of the steam equilibrium and eduction valves, *d*, *e*, *f*, fig. 14; the weight attached to these at once lifts them up out of their seats, and steam is admitted to all parts of the cylinder and pipes. Condensation from the cold surfaces of the metal goes on for some time, until, when the air is expelled, the steam rushes out through the shifting valve, placed at the lower part, either of the air-pump or of the condenser, with a sharp noise. The valves at this stage are all shut, and a vacuum is produced on the lower part of the cylinder. The steam valve, *d*, and eduction valve, *f*, are then opened, the equilibrium valve being kept closed, and the injection cock ad-

mitting the jet to the condenser being previously opened. The steam allowed to press upon the upper side of the piston forces it to the bottom of the cylinder. The descent of the plug-frame, *l l*, causes the pins and lappets to strike the levers of the steam

Fig. 14.



and eduction valves, closing them—the "equilibrium valve," by the same movement of the plug-frame, being opened. By this the equality of pressure on both sides of the beam is established, and the beam pulls up the piston to the top of the cylinder, the plug-frame causing the equilibrium valve to be closed, and the steam and eduction valves opened.

"No improvement," says Mr. Bourne, "in the principle of the single-acting or pumping engine, has taken place since its

parts were arranged by Watt in the manner here delineated. The great lever is now made of iron instead of wood. Parallel motions are employed instead of arch-head and chains, and some improvements have been made in the details of the valve-gearing and other minutiæ. But these modifications, though they may make the instrument more elegant and convenient, do not make it more effectual; and an engine made after Watt's primitive type would, with an equally effectual boiler, and an equal measure of clothing and expansion, do about the same amount of duty as the best of the modern construction."

ILLUSTRATIONS OF MILL AND MACHINE GEARING.

FIGURES 1 TO 36, PLATE I., AND FIGURES 1 TO 10, PLATE II. SCALE FOR ALL THE FIGURES, ONE INCH = ONE FOOT.

COUPLINGS AND CLUTCHES FOR SHAFTS.

SHAFTS are divided into two classes—those for heavy work, which are termed "shafts;" and those for light work, which are termed "spindles." In fig. 6, Plate VIII., we give an illustration (half an inch to the foot) of a shaft. The parts, *b*, *f*, in which the shaft revolves, are termed its "gudgeons," "bearings," or "journals." The parts on which the wheels, &c., which the shaft has to support, are fixed, are termed "bosses." The "journals" are terminated by projections termed "ruffs" or "collars." Fig. 5 is a transverse section of the boss of the shaft at *e* in fig. 6. The boss of the shaft has longitudinal grooves cut at four points—sometimes only two—of its periphery; corresponding grooves or slits are cut in the eye of the wheel, which is then passed over the boss, and firmly fixed thereon, by driving wedges, "keys," or "cottars" in the grooves. Fig. 8 is an illustration of a "spindle" or shaft for a small machine (one inch to the foot); *b*, *d*, are the journals; *a*, *c*, *e*, the bosses, with "key seats," on which to fix the wheels, &c.

Shafts are either "vertical" or "horizontal." In horizontal shafts the bearings or journals are as *b*, *f*, fig. 6. Fig. 7 is part of a vertical shaft, *f* being the "boss," on which to fix the wheel, and *g* the part in which the shaft revolves. The method of constructing the parts in which the journals and bearings of shafts revolve, will be described when treating of "Plummet Blocks," "Pedestals," and "Steps." (See Plate III.)

Where the power of an engine or other prime mover is to be transmitted to a considerable distance by means of shafts—where the distance is too long to admit of a shaft being made in one length—several lengths are joined by means of what are termed "couplings." In Plate I., figs. 1, 2, and 3 give a section, elevation, and end view of a "square coupling," *a*, *b*, being the two shafts to be joined, having square terminations, over which a square coupling box, *c c*, is passed, and secured by a "key," or driven tightly on. Fig. 4 (5, 6) is an illustration of a round coupling box, the ends of the shafts being circular. Fig. 7 (8, 9) is another form of square coupling, in which the coupling box is secured by bolts and nuts, as shown. Fig. 10 (11, 12) is a round coupling box, secured by a "key," *d*. Fig. 13 (14, 15) shows a method of joining two light shafts or spindles by two flanges on the end of each shaft, small bolts or rivets being passed through both flanges. Fig. 16 (17, 18) shows another form of square coupling box, where the end of each shaft is square, the coupling box being secured by bolts and nuts, *d d*; this form is fast going out of use. In fig. 19 (20) the ends of the shafts are square; but one, as *a*, is provided with a projecting snug, which goes into a corresponding depression or aperture in the other shaft—a round coupling box being passed over both, and secured by pins placed at right angles to each other, and passing through the coupling box and shafts. Fig. 23 (24, 25) is another form of round coupling box, secured by pins, *d*, passing through the box and shaft, and riveted into countersunk holes in the box.

In place of bringing the ends of the shafts to be joined square up, as in the previous examples, the ends are made to overlap each other, as in figs. 22 and 26. This form is known as the "half lap." The round coupling box is fastened on by means of a key, as shown in fig. 21. Figs. 29, 30, 31, 32, show other forms of coupling boxes, these being put on in two pieces, the angular projections of the one going into the indentations of the other. Fig. 35 is a section of the half, *e e*, of the box for fig. 32; fig. 36 of *d' d*, and 34 of *c c'* for fig. 30.

CLUTCHES.

Where two shafts are joined, it is sometimes requisite to have the means of quickly disconnecting them; so that while the motion of one is continued, that of the other is arrested. By this contrivance, one part of a machine can be arrested and put on at pleasure. One of the coupling boxes is capable of sliding backward and forward in a longitudinal direction upon the "boss" of the shaft, this being effected by having a projecting "rib" or "feather" on the shaft, with a corresponding groove in the eye of the coupling box. Thus the box is capable of being moved along the feather, but partakes of the motion of the shaft, and consequently revolves along with it. The faces of the clutches, as *c*, *d*, fig. 1, Plate II., are provided with corresponding indentations and projections; so that when the two are placed in contact, the motion of one shaft is communicated to the other. Thus, let *b e* the driving shaft, revolving on its independent bearings, and *a c*, the driven shaft, also revolving on its bearings, as in the drawing the two coupling clutches are shown in contact, the motion of *e b* is partaken of by *a c*. By moving the clutch, D, however, along the feather, the projections fall from the indentations of *c*, and although the shaft, *b e*, continues to revolve, carrying round with it the coupling box, *d*, the shaft, *a c*, has no motion; by moving D along the feather in the opposite direction, the projections of D fall into the indentations of *c*, and motion is given to *a c*. The part, *d*, of the "sliding clutch" is loosely embraced between the fork of a lever, which, on being moved from right to left, moves the clutch backwards and forwards in the feather, and thus throws the shaft, *a c d*, in and out of gear as desired. Fig. 3 is a section of the fixed clutch, *c*. Another form of clutch is shown in figs. 4 and 5, the sliding clutch, *d d*, moving along the feather, *f f*. The projections are so formed, that if the shaft, *g*, turns in the wrong direction, the clutch, *d d*, falls out of gear with the clutch, *c c*, and ceases to turn the shaft, *a*. So long as the shaft, *g*, turns in the right direction, the clutches being in contact, the motion of *g* will be communicated to *a*. Fig. 6 is a section of the clutch, *d d*.

Figs. 9 and 10 are two views of a universal joint or coupling. This is used where the direction of the shaft, *a a*, is at an angle to that of *b b*, the ends being coupled together by the links, *c c c c*, fig. 8.

Another and very generally used method of engaging and disengaging machinery, is by the "fast and loose" pulley. The two pulleys are of equal diameter and width, and are placed on the same shaft, close to one another. One of these is allowed to revolve freely on the shaft; the other is fixed. By passing the strap or driving-belt from the loose to the fast pulley, the shaft receives the motion from the prime mover, and *vice versa*. The loose pulley runs in a "journal" made on the shaft.

PEDESTALS, PLUMMET BLOCKS, STEPS.

Fig. 1, Plate III., is a side elevation of a pedestal for a horizontal shaft. The journal of the shaft, *c*, is embraced by two "brasses" or "bushes," *d e*, the "cap," *f f*, being bolted firmly down to the body of the pedestal, *b b*, by the bolts, *g g*. The pedestal is fixed to its base by bolts, A A. Fig. 2 is a section of the pedestal; E E shows the space through which the bolts, *g g*, are passed; *c* is the lower brass, *b b* the upper, *g* the "oil hole." Fig. 3 is the plan of pedestal with "cap" or "cover;" fig. 4, the plan without cover. Fig. 5 a is side elevation, and fig. 6 a section of another form of pedestal. This example is taken from M. Le Blanc's Drawing-book. Fig. 7 is a side elevation of pedestal, fig. 10 a section, fig. 8 a plan, and fig. 9 a plan of cover, adapted for a horizontal steam engine. *The scale to which all these examples are drawn is one inch to the foot.*

Where shafts are placed so as to run horizontally below a ceiling, the bearings are suspended from it, and are termed "hangers," or "gallows." Fig. 11 is a side elevation of a "hanger," fig. 12 a section, and fig. 13 a front view. Fig. 1, Plate IV., is a side elevation, and fig. 2 a front elevation of another form of hanger. *Scale for these figures, three-quarters of an inch to the foot.*

Shafts are sometimes carried along the face of a wall. The bearings in this case are supported by "brackets," as fig. 3, Plate IV., or fig. 4. Fig. 5 is a plan, and fig. 6 an end view of fig. 4. The pedestal is placed at *a*, between the snugs.

Fig. 7 is an elevation of a "step" for a vertical shaft, and fig. 8 a plan of the same. Fig. 9 is a section, and fig. 10 a section of the brass step, *x* being the space left for the tallow which lubricates the part *g*, fig 7, Plate VIII.

Fig. 1, Plate V., shows the arrangement used in a "flour mill," where the vertical shaft supporting the millstone is required to be moved up and down, so as to adjust the distance between the upper and lower millstones, and thus make the flour finer or coarser, as required; *a a*, the pillars which support the millstones; *c c*, the vertical shaft, supported on the step, *b*. By turning the nut, *g*, the lever, *e*, is raised or lowered, and acts correspondingly on the stud, *b*, on the end of which the brass step, in which the end of shaft *c* revolves, is supported. *Fig. 1 is drawn to a scale of one inch to the foot.* Fig. 2 is a side view, and fig. 3 a front view of lever, fig. 1; and figs. 4

PLATE V.

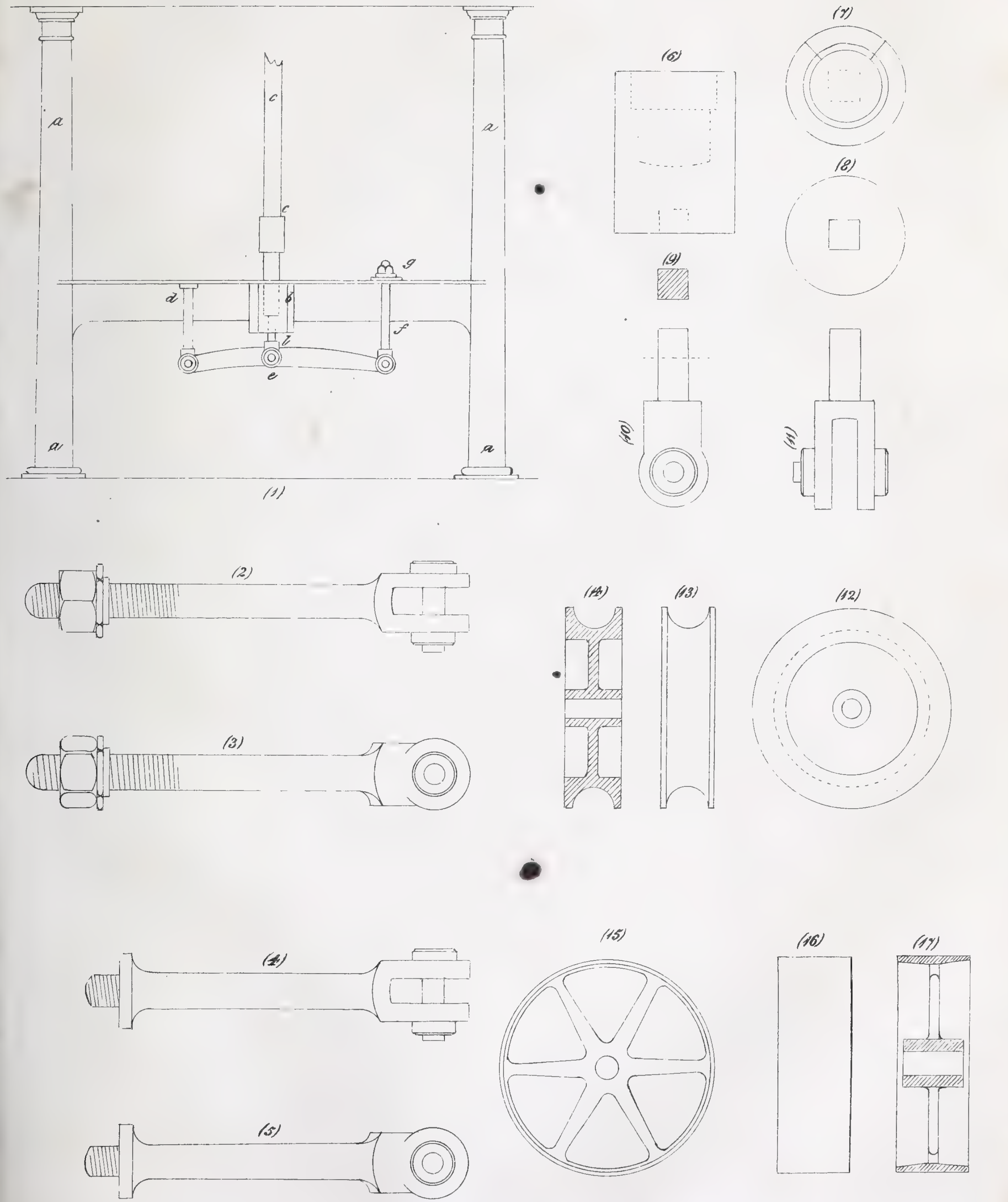
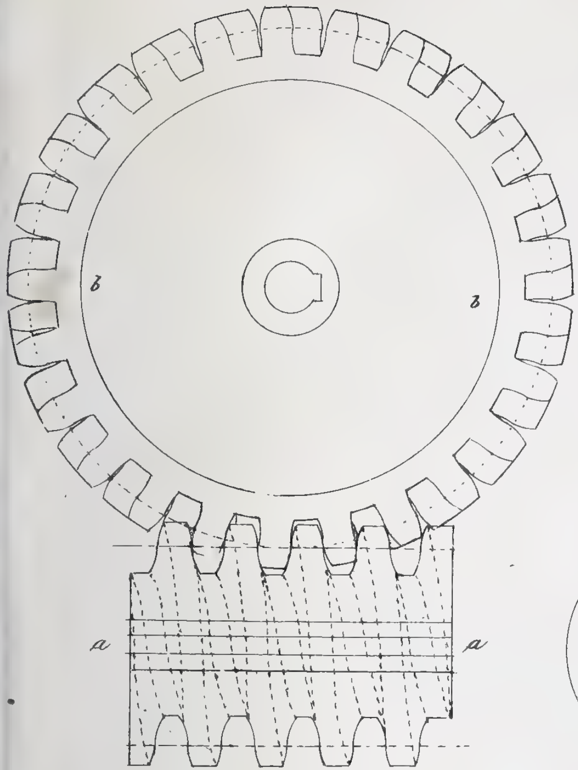
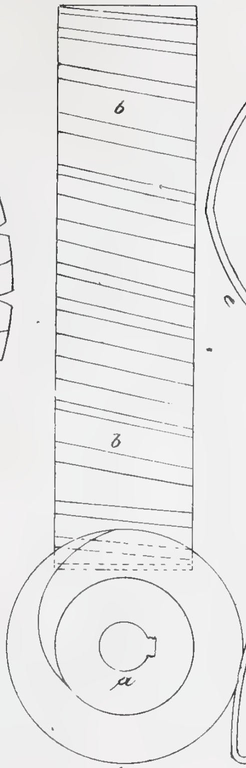


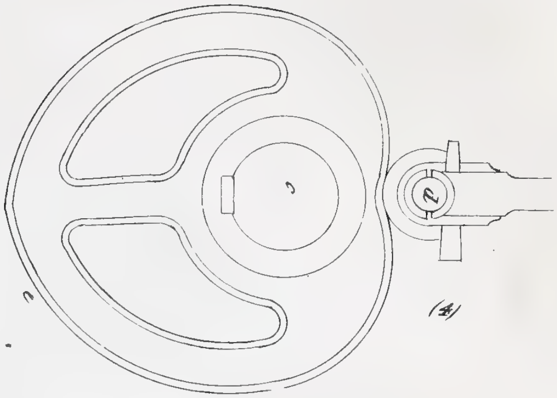
PLATE VI.

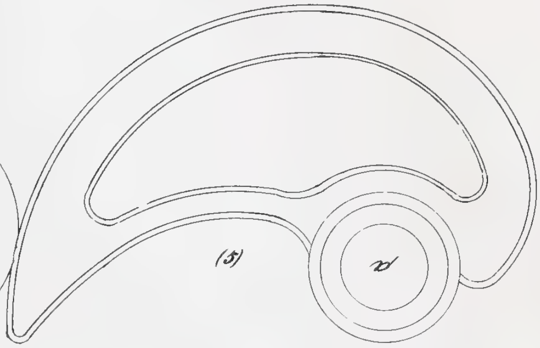


(1)



(2)





(3)

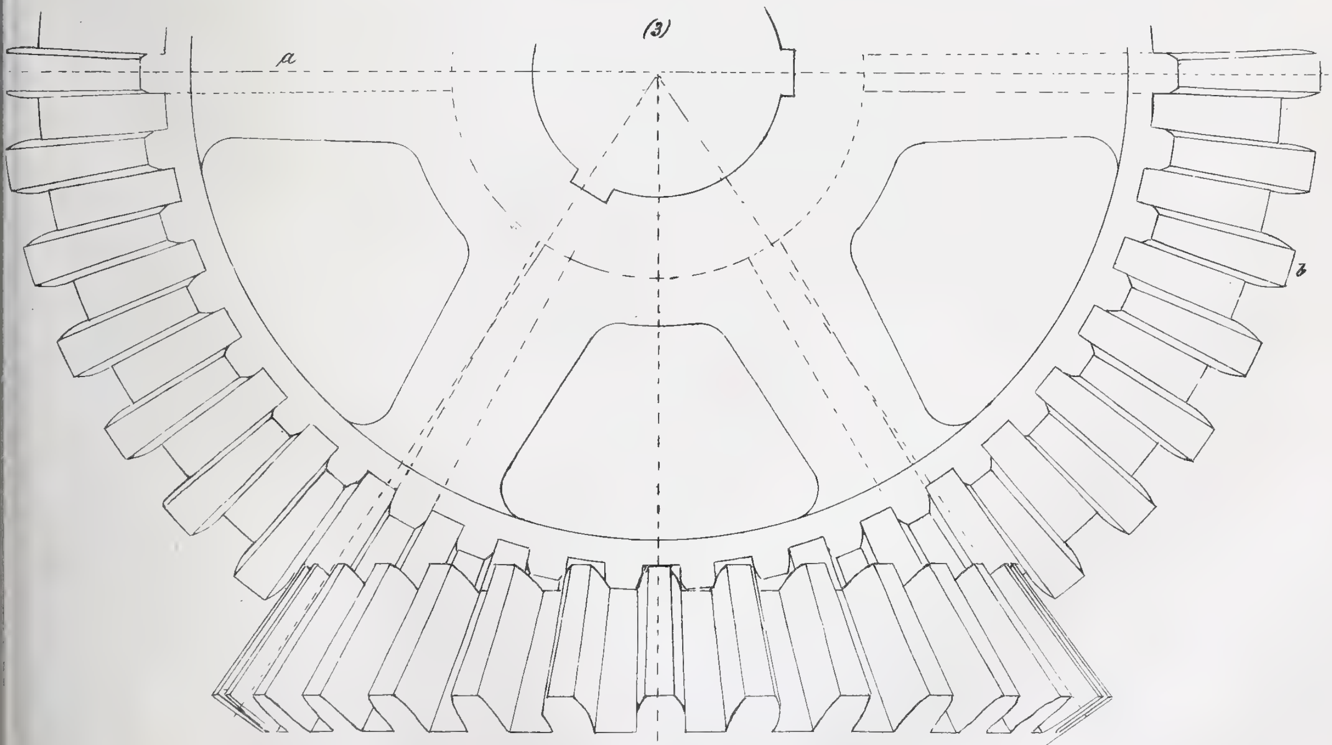


PLATE VII.

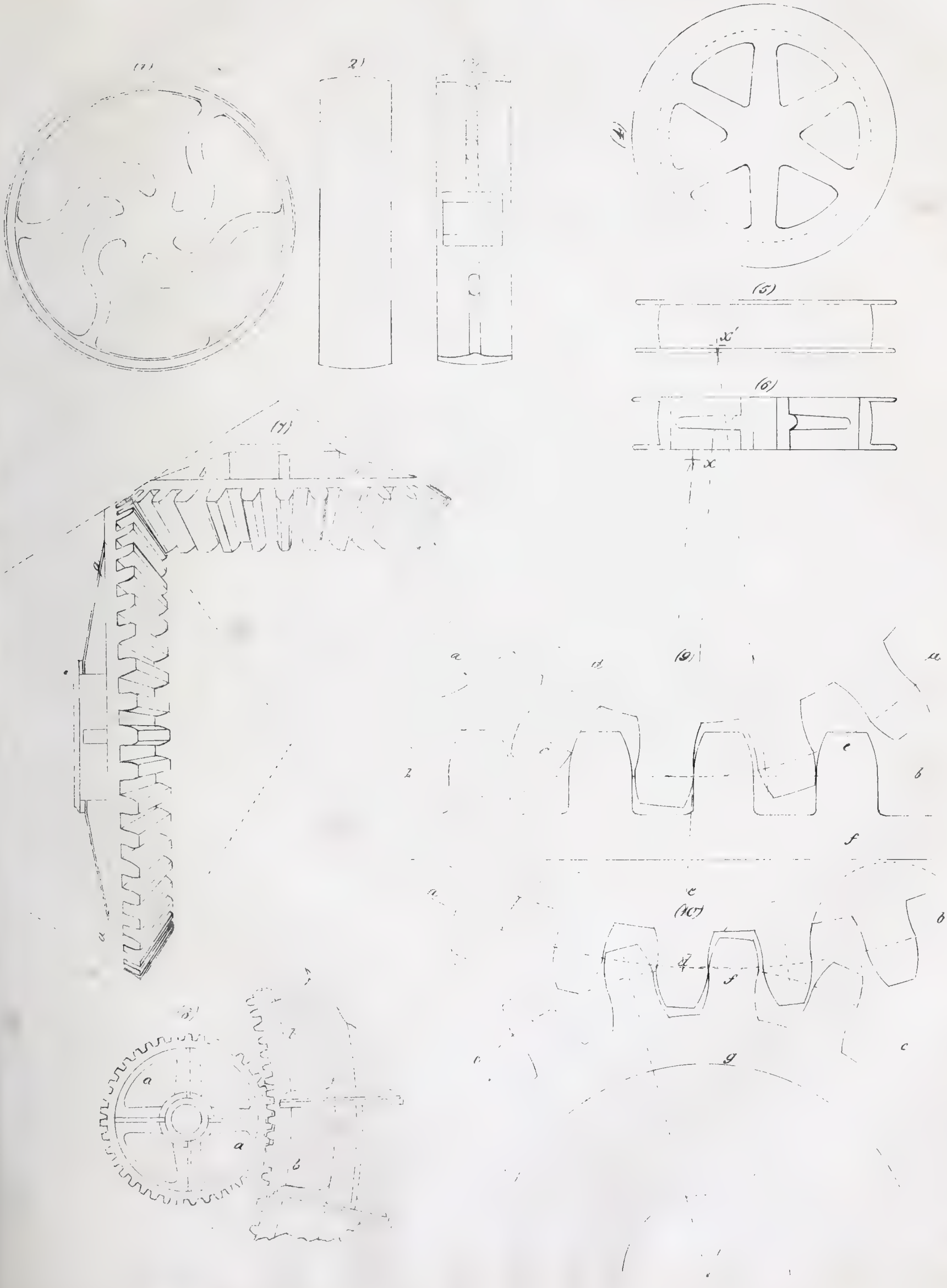
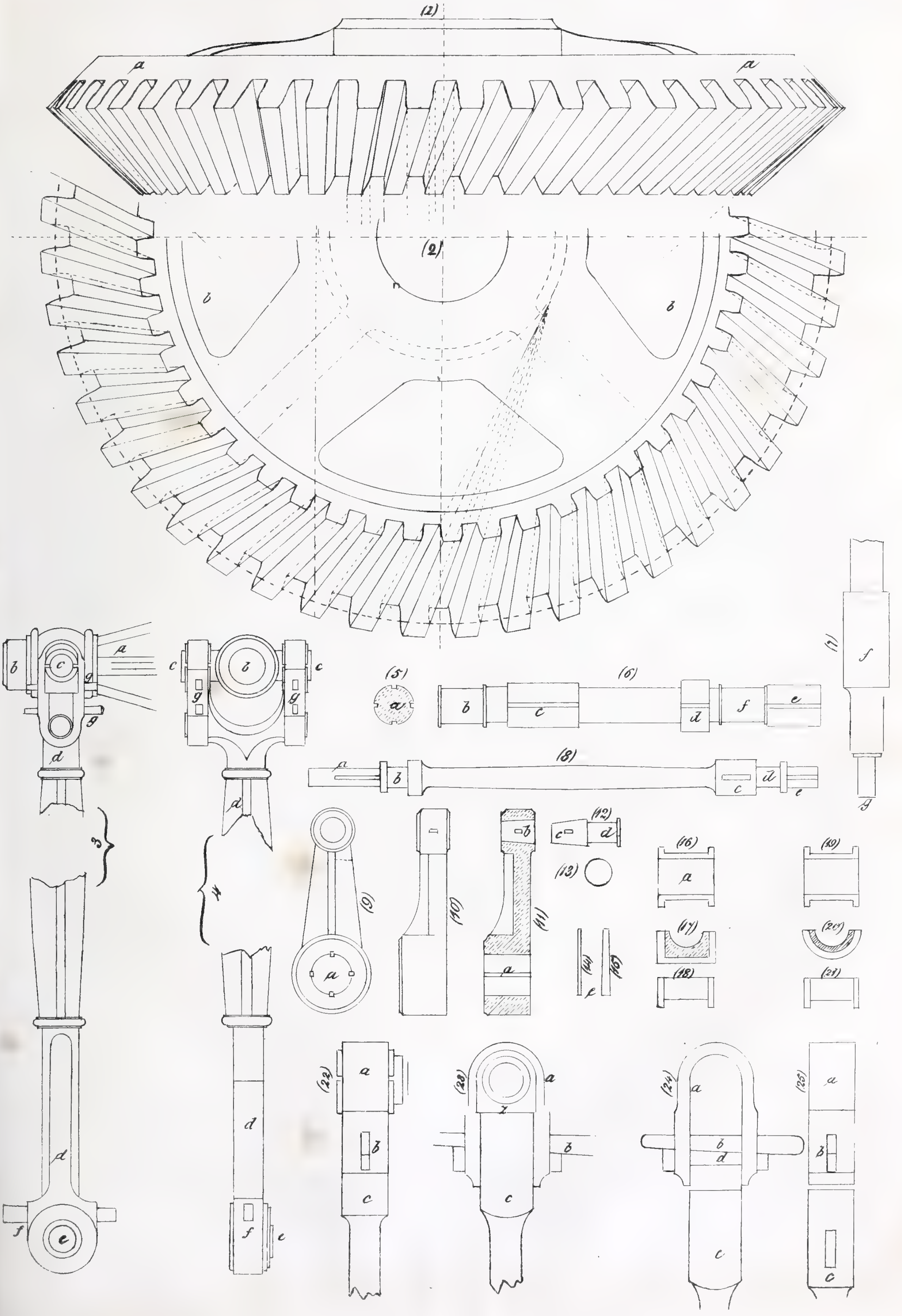


PLATE VIII.



and 5 of stud, *d*, *drawn to a scale of two inches to the foot.* Fig. 6 is a side elevation of brass step; and fig. 7, plan of top; fig. 8, bottom of step; fig. 10 a front, and fig. 11 a side view of stud, *b*, fig. 1; and fig. 9 a section through A B, fig. 10. *Scale for these figures, two inches to the foot.*

PULLEYS.

Fig. 12 is a side view of a rope or chain pulley used in collieries; fig. 13 an end view; and fig. 14 a section. Fig. 15, side elevation of a pulley with flat rim; fig. 16, edge view, and fig. 17 a section. *Scale of these figures, three-quarters of an inch to the foot.*

Fig. 1, Plate VII., is a side view, fig. 2, edge, and fig. 3, a section of pulley with curved arms. Figs. 4, 5, and 6, section of a pulley for a flat rope, used in collieries.

TOOTHED GEARING.

Fig. 7, elevation of bevil wheel, *a a*, and pinion, *b b*.

Fig. 8, illustration of annular wheel, *b b*, fitted to the interior of a water-wheel; *a a*, the pinion. On the shaft of this a drum or pulley is fitted, from which the power is taken by a driving-belt or strap. In the case of an annular wheel and pinion, the direction in which they revolve is the same. In the case of a wheel and pinion, as at fig. 10, the direction of the driven wheel is different from that of the driving wheel. The point, *x*, is the centre of the spur-wheel, *a a*; *a a*, the "pitch circle" of the wheel; and *c c*, that of the pinion. The point where they touch is that from which the divisions of the pitch circle, denoting the number of teeth, are commenced. The pitch of a wheel is the distance taken up by a tooth and a space, or the distance between the centres of two contiguous teeth. The centres by which the curves forming the flank of the teeth are found, are shown at *f*, fig. 10, and are in the centre of each tooth. The centres by which the curve of the projecting part of each tooth is found, is the centre of each space, as *d*.

Fig. 9 represents part of a rack and pinion. The centre of the pinion is at *x*. The points *c* and *f* are the centres from which to describe the curve of the teeth.

Fig. 3, Plate VI., represents another view of the bevil gear in fig. 7, Plate VII., *a a* being a face view of the wheel, *a a*, fig. 7, and *c c* a side view of the pinion.

Fig. 1, Plate VIII., *a a* is a side view, and fig. 2 a face view of a "skewed" bevil wheel, sometimes used in cotton machinery.

WORM WHEEL AND SCREW.

Fig. 1, Plate VI., front view; fig. 2, end (*two inch scale*); *b b*, the wheel with skewed teeth, to suit the pitch or curve of the screw, *a a*.

CAMS AND WIPERS.

Fig. 3, front view of a heart-shaped wheel, or cam. The rod, *d*, with friction wheel, will rise a height equal to the space between *c* and *d*, during one-half of a revolution of the cam, *c c*; during the other half it will fall the corresponding height. Fig. 5 is the form of a "wiper" used in "stamping mills." The form of the curve in this figure is known as the "involute."

CONNECTING-RODS—CRANKS.

Fig. 3, Plate VIII., is a side view, and fig. 4 an end view of a connecting-rod used in a beam steam-engine. The end of the beam is at *a b*; *c*, the centre, to which the link of the connecting-rod, *d d*, is attached; *g g*, the keys or cottars for tightening up the brasses. The crank pin is embraced by the brasses, *e*; *f* being the key or cottar.

Fig. 9 is a front elevation, fig. 10 a side view, and fig. 11 a section of a steam-engine crank. Fig. 12 is the crank pin, which passes into the eye, *b*, of the crank, and is secured by the cottar or key, fig. 15, 14, driven through the slot or aperture. In fig. 12, *d* is the part of the crank pin which is embraced by the brasses of the connecting-rod. (*Scale, three-eighths of an inch to the foot.*)

Another form of connecting-rod, used in high pressure engines, is shown in fig. 23, which is a front, and fig. 22 a side view; *a a*, the "strap; *c c*, the "butt," or end of the connecting-rod; *b b*, the key for securing the butt and strap together, and for tightening up the "brasses;" 1, 2, the crank pin. Figs. 24 and 25 give the parts in detail; *a* is the front view of the "strap;" *a*, fig. 25, the side or edge view, with a hole cut in each prong, or fork, through which to pass the "key," *b*, and the "gib," *d*, fig. 24. In fig. 24, *c* is the front view, and in fig. 25 the side or edge view of butt of connecting-rod, with aperture or "slot" cut in it, to allow of the key and cottar passing through.

Fig. 16 is plan of lower "brass," or "bush," 2 (fig. 23); fig, 17, section; and fig. 18, end view. Fig. 19 is plan of upper brass, *d* (fig. 23); fig. 20, section; and fig. 21, end view. *Scale for figs.* 16 *to* 25, *three-quarters of an inch to the foot.*

MR. NASMYTH'S OIL TEST.

In all the contrivances which have been proposed as oil tests, a most important element has been left out, viz., *time*; inasmuch as the evil which is experienced from the use of a bad quality of oil, is only developed after the lapse of several days, when, by the action of the oil upon the metal with which it is in contact, together with the action of the air, such oils become viscid, and begin to clog instead of facilitating the movements of the parts of the machinery it was intended to lubricate.

In the more delicate descriptions of machinery, such as chronometers, watches, clocks, &c., such a defect as the thickening of the oil by lapse of time is a most serious evil; and in examining into the comparative fitness of certain oils for such applications, if we do not include *time* as an element in our examination, we shall be led to form most false conclusions, inasmuch as it is the case, that for the first day or two, some kinds of oil (linseed oil, for example) perform the lubricating duty very well; but at the end of the second or third day, they become so thick and viscid as to entirely arrest the motion of the machinery.

The most valuable quality in an oil intended for the lubrication of machinery, is *permanent fluidity.* That oil which will for the greatest length of time remain fluid in contact with the iron or brass, is, without doubt, the most useful for the purpose. Hence, as before said, the necessity of including the element of *time* in any experiment on the comparative value of such oils.

Some idea may be formed of the importance of having the means of arriving at correct conclusions on this subject, when we know that, in some spinning establishments, there are upwards of 50,000 spindles in motion, at the rate of 4,000 or 5,000 revolutions per minute! The slightest defect in the quality of the oil in such a case, by its becoming viscid, tells in the most serious way upon the quantity of fuel consumed in generating the power required to maintain at this high velocity such a multitude of moving parts. The slight increase of fluidity consequent on the rise of temperature, caused by the lighting of the gas in the rooms of a cotton-mill, makes a difference of several horses power in the duty of the engine of an extensive establishment.

The oil test we have now to describe, and which is an invention of Mr. Nasmyth's, consists of a plate of iron four inches wide by six feet long, on the upper surface of which six

RESULTS OF OIL TEST.

DESCRIPTIONS OF OIL.	First.		Second.		Third.		Fourth.		Fifth.		Sixth.		Seventh.		Eighth		Ninth.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Best Sperm Oil	2	$8\frac{1}{2}$	4	2	4	$5\frac{3}{4}$	4	6	4	6	4	6	4	$6\frac{1}{8}$	Stat.		....	
Common Sperm Oil	1	7	3	9	4	$6\frac{3}{4}$	4	11	5	$1\frac{1}{2}$	5	4	5	$6\frac{3}{4}$	5	$7\frac{3}{8}$	5	8
Galipoli Oil	0	$10\frac{1}{4}$	1	$2\frac{1}{4}$	1	6	1	$6\frac{1}{2}$	1	$7\frac{5}{8}$	1	$8\frac{3}{4}$	1	9	1	$9\frac{1}{4}$	1	$9\frac{1}{2}$
Lard Oil	0	$10\frac{1}{4}$	0	$10\frac{1}{2}$	0	$10\frac{3}{4}$	0	$10\frac{3}{4}$	0	$11\frac{3}{4}$	Stat.		....		....		....	
Rape Oil	1	$2\frac{1}{2}$	1	$6\frac{1}{4}$	1	7	1	$7\frac{1}{8}$	1	$7\frac{1}{4}$	1	$7\frac{1}{4}$	1	$7\frac{1}{4}$	1	$7\frac{3}{4}$	Stat.	
Linseed Oil	1	$5\frac{1}{2}$	1	6	1	$6\frac{3}{4}$	1	$6\frac{1}{4}$	1	$6\frac{1}{4}$	1	$6\frac{1}{4}$	1	$6\frac{3}{4}$	Strat.		....	

equal-sized grooves are planed. This plate is placed in an inclining position, say one inch in six feet. The mode of using it is as follows:—Suppose we have six varieties of oil to test, and we are desirous to know which of them will for the longest time retain its fluidity when in contact with iron, and exposed to the action of the air; all we have to do is to pour out *simultaneously*, at the upper end of each inclined groove, an equal quantity of each of the oils under examination. This is very conveniently and correctly done by means of a row of small brass tubes. The six oils then make a fair start on their race down hill; some get ahead the first day, and some keep ahead the second and third day; but on the fourth or fifth day the truth begins to come out: the bad oils, whatever good process they may have made at the outset, come soon to a stand-still, while the good oil holds on its course, and by their gradual coagulation, at the end of eight or ten days, there is no doubt left as to which is the best; it speaks for itself, having distanced its competitors by a long way. Linseed oil, which makes capital progress *the first day*, is set fast after having travelled 18 inches, while second-class sperm beats first-class sperm by 14 inches in nine days, having traversed in that time 5 feet 8 inches down the hill.

PHRENOLOGY.

CHAPTER XV.

CONCLUDING OBSERVATIONS ON THE ART OF PRACTICAL PHRENOLOGY.

Accurate knowledge in regard to the different regions of the brain, gives facility in finding the locality of the different organs. There are several bony prominences on the skull, which do not indicate developments of the brain: these are the mastoid prominences behind the ears; the crucial spine of the occiput, or bony projection situate below Philoprogenitiveness; the zygomatic process, extending from the cheek-bones to the temples; and the ridge in the middle of the coronal surface of the skull, occasioned by the longitudinal sinus. The individual organs extend from the medulla oblongata, or top of the spinal marrow, to the surface of the cerebrum or cerebellum. The line, or axis, passing through the head from one ear to the other, connecting together the two *meatus auditorii*, or openings of the ear, would nearly touch the medulla oblongata, and hence is assumed as a convenient point from which to estimate length. The distance from the centre of this line to the peripheral surface of the brain, measures the length of the organ there situated. A line, for instance, drawn from that point to that part of the surface of the brain where the organ of Comparison is situated, measures the length of that organ. But the size of an organ depends upon its breadth, as well as its length; the breadth is estimated by its peripheral expansion at the surface. Each organ has some resemblance to an inverted cone, having its apex at the centre of the axis, and its base at the surface of the brain. As a general rule, the size of the organ indicates its power. The same general law that, under like conditions, proportions the strength of a body to its size, and is everywhere found coupling power with large dimensions, applies as infallibly to the cerebral organs as to all other organs in the animal system, and all other parts in the system of things; the same rule that ascertains the contents of a cone, ascertains the contents of the cerebral organs. The size of an organ is therefore essentially different from its prominence at the surface of the brain. If an organ possesses an ample development, while its neighbours that bound it on every side are defectively developed, then it will present a prominence; but if the organs surrounding it are equally well developed, no prominence at the surface will be perceived, but a general fulness, indicating an equal extent of development. It is precisely the same in regard to a defectively developed organ. Both the prominences and recessions presented at the surface, speak only a relative, not an absolute language. The only true mode of ascertaining size, is to estimate, as near as possible, the dimensions of the organ at the surface of the brain, and the distance of that surface from the centre of the axis. In an equal development of the organs, a difficulty may occur in estimating the dimensions of an individual organ at the surface, as no prominence will then be presented; and hence, as many would infer, no positive data upon which to ground an estimate. In a case of that kind, the superficial dimensions may be calculated from the general size of that region of the head where the organ is situated. In the equal development of a number of organs, their superficies will increase in proportion as they recede from the axis. The periphery of the whole head must obviously increase in the direct ratio to its size. The periphery of its several parts must follow the same general rule. It therefore follows, as a necessary consequence, that in equal developments of different organs, the breadth of each organ will increase in proportion to the increase of its length; hence, in cases of that kind, the length of an organ affords the data from which its breadth may be estimated. In regarding size as indicative of power, care must be taken to distinguish between power and activity. The one has reference to the *energy*, the other to the *rapidity*, with which the faculties act. The one accomplishes by a slow but sure movement, the other by a quick and sudden turn. While the balance-wheel of a watch exhibits activity, the elements of power are manifested in the walking-beam of a steam-engine; hence you *perceive* that a watch has a sanguine nervous temperament, while a steam-engine has a *bilious lymphatic*. The same quantum of power, other circumstances being equal, ought to be attended with the same degree of activity; which is, in fact, nothing more than a facility and quickness in the exercise of it by the individual. The general rule, that size of organ indicates its power, must of course be subject to the condition of other things being equal. The circumstances under which individuals have been placed, and their agency in calling forth the faculties into active manifestation, together with the different temperaments of individuals, or the strong original tendencies of their constitutions, are disturbing elements in the application of the general rule. Their disturbing forces can to some extent be estimated, and the effects they produce be calculated upon in the modification of size. Exercise, in effect, varies power, by rendering it more available. The size of the organ gives the tendency to the proper exercise of its functions. The tendency to that exercise is also given by the presentment of external objects fitted by nature to excite to activity. Let those objects be wanting, and the power itself might slumber, and would possess less aptitude to exert itself in proportion to the paucity of objects that could call it into exercise. Men are variously situated in regard to the conditions under which they act, and the circumstances that surround them: hence, faculties of the same degree of strength in different individuals may have been exposed in different degrees to those objects that constitute their natural aliment. From this results the difference in the opportunities afforded for their exercise. To estimate properly the influence of this modifying cause, the circumstances in which the individual has been placed must be considered. That influence, under ordinary circumstances, seldom forms a large item in the estimate, because the kind of objects fitted to call into exercise the activities of the mind, may be found in almost every sphere of human life. We all breathe the same atmosphere, tread the same earth, are overhung by the same heavens, and surrounded by the same kind of natural objects. Had the destiny of a Franklin penned him within the limits of a sheepfold, we might not, at this time, have seen the lightning of heaven controlled by human agency; but his faculties would, nevertheless, within a limited sphere, have sought and found the objects they were framed to act upon. "Orfila," says the *Medical Times*, "the best known of living scientific men, doctor of medicine and surgery, professor of chemistry, and dean of the most distinguished medical faculty in the world, member of the academy of medicine, commander of the legion of honour, peer-elect of France in 1844, so illustrious alike in rank and deeds, was in 1804 a *poor pilot boy* in a miserable Spanish coaster."

To estimate properly the disturbing force of exercise as a modification of size, it becomes necessary to be acquainted with individual history. The modification of size most important to be attended to, results from the original constitution or

quality of the body. These are indicated by the *temperament* of the individual.

In the reduction of this science to practice, after ascertaining the general size of the head, the next point to be settled is—are the different regions of the brain and the organs that compose them equally developed? If so, the tendencies to action will be every way alike; the individual will exhibit the most opposite phases of character, and his actions will be called forth, not by the predominance of faculties, but by the predominating influence of the circumstances in which he may happen to be placed. If those circumstances are in their nature calculated to excite the propensities, the rein will be given to them. If to call into exercise the higher sentiments, they, for the time being, will exercise a controlling influence; the one would lead to sin, the other to repentance, and these together would form no inconsiderable item in his biography. Such a person was Sheridan. In the estimate of such a character, or rather such an absence of all fixed character, the circumstances should be alone considered. But these are varying every hour. An individual of this description would therefore be a subject that would set calculation and estimate, and every kind of conclusion at defiance; excepting always the conclusion, that nothing could be concluded upon. Possessing tendencies to action, and capacities of acting, every way alike, he would be the unresisting subject of circumstances; a case of this kind, however, is of rare occurrence.

The subject next to be ascertained would be, whether any one organ was developed to any considerable extent beyond others. If so, its controlling influence will pervade, in a greater or less degree, every department, whether of feeling or of intellect. It would constitute what is usually termed a leading feature, or prominent trait, in his character. A large Love of Approbation would seek its appropriate aliment, through all the means that could be rendered available for that purpose by the faculties that were combined with it.

In no instance is this more strikingly exemplified, than in the career of the late Sir Francis Burdett. We cannot forbear quoting a newspaper sketch of him, published in 1837:—"At one time we find him as the leader of the radicals, standing almost alone in the Commons against the ancient oligarchy, launching his thunder against the boroughmongers, sent to the Tower for defence of a private citizen's rights, and encountering a government prosecution and its consequences, for his indignant denunciation of the magistracy and yeomanry who cut down a peaceable and unarmed multitude met at Manchester for the purpose of petitioning for Parliamentary Reform. At another time we find him coldly supporting the Grey administration in its forward movements, but giving it his hearty support whenever the Stanley and Graham obstructive interests predominated; and, when the Melbourne administration came into power, with the promise, at least, of carrying out nearly all the principles which he formerly professed, we find him abandoning all those principles, and regularly enlisting in the ranks of the men who had ever been the enemies of that reform which it had been his glory to advocate.

"Does the history of England present another such instance of inconsistency and imbecility? And does the philosophy of Stewart and Reid, with their understanding and will, and judgment and imagination, and memory and common sense, afford any explanation of the extraordinary and pitiable changes which take place in the conduct of public men?

"The truth is, that in looking for the cause of Sir Francis Burdett's tergiversation, we must come to the science of Gall and Spurzheim and Combe. Sir Francis has always had an exceeding 'love of approbation.' When a very young man, his desire for applause took the direction of literary fame, and he was proud to figure as one of the interlocutors in John Horne's 'Diversions of Purley.' Subsequently, and still under the influence of Horne Tooke's more powerful mind, it was gratified with the shouts of the multitude, and the title of 'England's Glory and Westminster's Pride.' Even in his palmiest days, when these misgoverned islands 'rung from side to side' with his name, and he was the object of admiration and almost idolatry to every youthful reformer, it was understood that his Westminster committee could keep him to his professed principles only by administering strongly to his vanity, and by persuading him that at the head of the reformers he was indeed 'England's Glory.' The firm-minded, right-principled, and venerable Major Cartwright early exposed the hollowness of his pretensions, the narrow grasp of his intellect, his slender hold of principles, and the low source of his ambition. The man is the same still, though his course of conduct has changed, as a stream is the same though it finds its way into another channel. The motive of Sir Francis—his spring of action—is the same. Applause has been his daily food. When he was young and ardent he sought it from the multitude, and now when he is old and idle he seeks it from the ancient dowagers in trousers, who adorn the house of hereditary wisdom. His daily vocation was gone long before the Reform Bill was introduced. Better intellects had come into the field that had been his own exclusive possession. Reform principles were advocated with a power that he never possessed, even in his most energetic days. Instead of being at the head of the glorious army that was advancing with firm steps and well-pointed arms against the old strongholds of corruption, he had but a subaltern's command, and less than a subaltern's reputation. No shouts from admiring crowds burst upon his ear. He disliked the toil which brought him no "glory," and took the first opportunity of stealing away to the enemy's camp, and there found that flattery and deference which had become necessary to his existence."

The next inquiry should be: Are any particular regions of the brain, or sets of organs, more extensively developed than other organs or sets in the same head? If so, their combined action will strongly influence the general course of conduct. Is the region *round*, *above*, and just *behind* the ear, better developed than any other?—Secretiveness, Combativeness, and Destructiveness, may be presumed to predominate. Does the same occur in regard to the region in front of the ear?—Acquisitiveness and Constructiveness predominate; the former seeking a gratification through the medium of the latter. Is the upper back part of the head more largely developed than other parts?—Self-esteem, Love of Approbation, and Firmness may be expected to communicate their modified result to the whole character. Is the upper central part of the head similarly developed?—Cautiousness, Conscientiousness, and Ideality may be expected to carry through the entire mental economy the sense of fear, of justice, and of beauty. Is a larger quantity of cerebral matter found in the upper frontal region of the brain, than in other parts of it?—we may calculate that Hope will clothe the future in brightness; that Veneration will look up with awe and reverence to a superior being; and that Benevolence will be ever ready to extend relief to the wretched. The character will thus exhibit goodness rather than greatness. In the large development of the frontal region of the brain, the strong operations of an ever-active intellect are to be found.

After acquiring a facility in estimating the influence of one predominating faculty or of particular sets of faculties, the next object to acquire, is the modifying influence which one faculty or set of faculties will exercise over others. Veneration, for instance, when influenced by faith, hope, and charity, and aided by Conscientiousness, will regard the Supreme as all that man can desire or love, and all that he should adore and worship: but large Veneration, where there is a deficiency of faith, hope, charity, and Conscientiousness, and an energetic development of Acquisitiveness, will make gold the object of its worship, and bow down at the shrine of wealth. The same combination, assisted by Self-esteem, will lead to the veneration of titles, of kings, and kingly state. A large Ideality, aided by large Hope, and with moderate Cautiousness and weak reflecting faculties, constitutes the wild visionary projector. The same combination, with small Conscientiousness and Benevolence, and large Acquisitiveness, constitutes the gambler. A miser, in the money sense of the word, has large Self-esteem, large Acquisitiveness, moderate Benevolence and deficient Love of Approbation. Destructiveness, Combativeness, Secretiveness, Firmness, Self-esteem, and Love of Approbation constitute the warrior; death seeks his victims through all these organs largely developed. Cunning and stratagem result from large Secretiveness, uncontrolled by Conscientiousness. Courage and

perseverance result from Combativeness and Firmness; honour, ambition, and a thirst for praise and greatness, from Self-esteem and Love of Approbation. The same combination existing in the virtuous and upright man, is hallowed and controlled by Conscientiousness, Veneration, faith, hope, and charity. The practical applications of the science are numerous and important. In mental derangement, in education, in jurisprudence, its principles and practice become interesting objects of inquiry. The phenomena of disease can only be understood by a reference to healthy action. This science, by investigating the action of the faculties in health, their relation with each other, and their connection with the organization, with the view of arriving at the condition under which they act, is prepared to take enlarged views of medical ethics, and to suggest the proper remedy for every mental alienation; education is, or should be, the cultivation of the mental faculties by supplying each with its proper aliment. What is the object and end of all jurisprudence, civil or criminal? It is the collection of general principles, and their application to human acts, so far as those acts affect the rights or privileges of others; or, in other words, it is the ascertaining and embodying of the relations existing between man and man, arising from the familiarity of intercourse. But all these relations will be understood and acted upon, when all the faculties are brought to act in harmonious concert with each other. Then man will have attained the ultimate perfection of his nature, and the same general principles that are now reposing in black letter, and slumbering beneath the lumber of ten thousand volumes, will bind together the framework of society, and be constantly evolving in all their beautiful proportions of life, from the warehouse of the merchant, the shop of the mechanic, and the homestead of the agriculturist.

COMPENDIUM OF LOGIC.

CHAPTER X.

PART V. ON THE DISCOVERY OF TRUTH (CONTINUED)—PRINCIPLE OF THE INDUCTIVE SYLLOGISM—METHOD OF REASONING IN THE SCIENCES—NEW TRUTHS—CONCLUSION.

In last chapter we explained the nature of Inductive and Deductive reasoning, distinguished perfect from imperfect Induction, and showed how the latter, though yielding only a presumptive inference when viewed independently of other arguments, constitutes the basis of inductive science, and carries us upward to generalizations, which, when confirmed by concurrent evidence, have often the force of demonstration. We now proceed to consider more closely the logical principles involved in this kind of argument; and then we shall bring our imperfect compendium to a close, by examining the sources of our knowledge, and the method of reasoning, with a view to the discovery of truth, pursued in the sciences.

PRINCIPLE OF THE INDUCTIVE SYLLOGISM.

Induction has been termed a peculiar form of the syllogism. This, if it be true at all, can only be true of the argument derived from induction, in the literal sense of the word. We prefer, however, to say that the argument derived from induction may, like every other argument, be stated in the form of a syllogism. Nay, it is by stating an argument explicitly in this complete or developed form, that its true nature is seen; and therefore we shall readily perceive, by doing so, the kind of inference that is logically drawn from a perfect and imperfect induction respectively:—

Argument from a Perfect Induction.

A, B, C, D (and so on to Z), are significant symbols;
But these are all the letters of the alphabet;
Therefore, all the letters of the alphabet are significant symbols.

Argument from Imperfect Induction.

Our ancestors, and all other men who formerly lived, have died;
But what is true of all who formerly lived, is probably (or certainly) true of all men;
Therefore, it is probably (or certainly) true that all men are mortal.

Now, in the first of these arguments, derived from a perfect induction, the nature and extent of the minor premiss are decided by the very fact of the induction being assumed to be perfect. In the second, the extent or force of the conclusion depends upon the major premiss (which happens in this case to follow the minor, the natural order being slightly inverted). If we assume that what is true of all who formerly lived, as far as respects their mortality, is *probably* true of all men, then we are enabled to conclude, by a strictly logical process, that *probably* all men are mortal. And if we assume that what is true of these is *certainly* true of all men, then we are authorized to conclude, by an equally logical process, that all men are *certainly* mortal. But, in point of fact, the particular induction on which the argument is founded does not authorize us to assume either the one or the other. The two premisses have no inferential connection. Even in the argument derived from a perfect induction, the premisses are quite independent of one another. We may know that A, B, C, D, &c., are significant symbols; and yet we may not be aware that this enumeration of letters, from A to Z inclusive, constitutes the whole of the alphabet. The fact happens to be quite familiar, yet it by no means follows from the statement that each of the letters enumerated is a significant symbol. We know, for example, that Mercury, Venus, Mars, &c., shine with borrowed lustre; yet we do not positively know that these are all the planets; therefore, we cannot certainly infer that *all* the planets shine with borrowed lustre. We may conclude that they probably do so; but even this *probability* does not logically follow from the fact, that all the known planets borrow their lustre.

Yet it is acknowledged, that in every case in which we do really generalize from an imperfect induction, we do assume the probability or certainty that what is affirmed or denied of each of the particular cases enumerated, may be affirmed or denied of the whole class to which such cases belong. Unless we were somehow authorized to proceed upon that assumption, we could not be justified in generalizing at all. To return, therefore, to the generalization derived from that imperfect induction which we have exhibited syllogistically, and taking, in the first place, the lowest assumption—what is the ground upon which we assume that what is true of all men who formerly lived, is *probably* true of all men whatever? This assumption is evidently founded on *another* induction—an induction of the many uniformities observed in nature. We find from experience, that what is observed to constitute invariably a characteristic of a number of beings or objects that resemble each other in certain essential qualities, *generally* belongs to every other being or object of the same class, as far as our own observation, or that of others, extends. We find from the same experience (which is a natural or spontaneous induction), that if the observed characteristic does not form an essential part of the nature, condition, or uses of the beings or objects in question, it sometimes belongs to many of the class without belonging to the whole; but the more the individuals that it does belong to, of such as come under our cognizance, the greater do we find from experience the likelihood that it will belong to other individuals of the same class. Hence we require, in such cases, very numerous examples, that is to say, a very extensive induction, to lead even to the *probable inference*, that what has been observed as a characteristic of a part is a characteristic of the whole; and the general mistake, which so long prevailed, as to the whiteness of *all* swans, though founded on the whole experience of all the civilized world for thousands of years, will show that in such non-essential matters, even a probable inference, drawn from a highly extensive induction, may be a false inference.

When, however, the characteristic observed is something that is seen or known to form an essential adjunct of the being or object, or something that is useful in connection with it, or rendered in some degree necessary by its position in the world, then do we find from experience that such an essential characteristic is seldom or never wanting in any individuals of the class to which our own observation, or that of others, extends; and hence a very few cases of that kind—a very limited induction—sometimes even a single case, provided it be well authenticated, constitutes the basis of a general inference,

which will be received as probable, or highly probable, or even as amounting to a moral certainty, according to circumstances. These circumstances, be it observed, do not consist in the extent of that particular induction of cases from which the generalization is drawn, but in the extent of a previous induction, which determines the degree of probability attachable to generalizations from certain classes of facts. Thus, in the preceding example, the major premiss, that "what is true (as respects mortality) of all who formerly lived is probably true of all men," is not, and cannot be, inferred from the induction that "all who formerly lived have died," but from a previous induction, the result of observation and experience, from which we derive the conclusion that nature is generally uniform in her operations.

But here an apparent difficulty meets us. If we arrive at the conclusion that the order of nature is uniform from a preceding induction, what will be the major premiss of the argument from that induction? If this is likewise the result of a previous induction, still we must arrive at an ultimate induction, from which the conclusion must be drawn, independently of any other induction. This argument is urged by Mr. Mill as fatal to Whately's assumption, that every inductive argument may be resolved into a syllogism. "If we throw the whole course of any inductive argument into a series of syllogisms," says Mr. Mill, "we shall arrive by more or fewer steps at an ultimate syllogism, which will have for its major premiss the principle, or axiom, of the uniformity of the course of nature. Having reached this point, we have the whole field of induction laid out in syllogisms, and every instance of inference from experience exhibited as the conclusion of a ratiocination, except one; but that one, unhappily, includes all the rest. Whence came the universal major? What proves to us that nature is governed by general laws? Where are the premisses of the syllogism of which that is the conclusion? Here, at least, is a case of induction which cannot be resolved into a syllogism."

Now, by a "case of induction," Mr. Mill, according to his own definition, must mean a conclusion or argument derived from an *imperfect induction* in the literal sense of the words. He therefore affirms, that if the uniformity of nature's laws is a conclusion derived from induction, the argument by which it is derived cannot be resolved into a syllogism. If he had said that, being an *ultimate induction*, it cannot be resolved into a syllogism having for its major premiss a *prior induction*, we should have been compelled to admit the truth of the statement, though not the truth of the inference which Mr. Mill deduces from it. In this case (that of a conclusion derived from an ultimate induction), we grant that the major premiss of the syllogism cannot be derived from a prior induction—we find this major premiss in a truth which has only to be stated to command immediate assent, and which must, therefore, be intuitive and elementary. The ultimate or primary inductive syllogism, with its *universal major*, as Mr. Mill somewhat ironically terms it, may therefore be stated as follows:—

> *What we see and know of nature's works is sufficient to illustrate her general principles of operation.*
> But what we see and know of nature (this, that, and the other case) shows uniformity of principle in her operations;
> Therefore, as a general rule, the principle of nature's operations is uniformity.

Now, we conceive that the major premiss of this syllogism (which premiss we have distinguished by italics), or some equivalent proposition, constitutes that universal major, or rather we should say, the ultimate major, to which Mr. Mill alludes, and of which he requires the origin. The true universal major is the conclusion of the syllogism, proved by the induction stated in the minor premiss, along with the principle stated in the major, that "what we see of nature's works is quite sufficient to illustrate the general principles." This, being the ultimate major, cannot be derived from any other induction. We intuitively feel and know it to be true. It is not arrived at by a process of reasoning; we take it for granted as a truth, and reason and act upon it; and this is the only account we can give of an intuitive process.

But if we are entitled to assume, as an intuitive truth, that what we see of nature's operations illustrates the general principle on which the whole are conducted, might we not equally assume the same to be true in each particular case of induction, without the necessity of reasoning back by a series of inductive arguments until we arrive at one which is based upon this intuitive truth, combined with a general induction of many inductions? We see or know, for example, that all men who formerly lived have died. This is the result of one induction. Are we not entitled to assume the existence of an intuitive conviction, that what we have seen or learned, in this particular department of nature's operations, illustrates the general principles on which she will continue to operate, in respect of human mortality; and hence to infer that all men are mortal, without going back to a general induction based on a general intuitive conviction with reference to *all* the operations of nature? This is a point which we must leave the reader to decide for himself. Enough that there exists an intuitive tendency in the human mind to expect that the same uniformity which characterizes what is seen and known reigns throughout all nature; and this is what constitutes the basis of inductive reasoning—the key which opens the recesses of nature's most hidden secrets.

METHOD OF REASONING IN THE SCIENCES.

"What is truth?" is a problem which engages the united efforts of all the sciences. Logic, as the science of reasoning, enters as an element into all of them, more or less; yet it is evident that many important truths are discovered without reasoning. Whatever is a subject of positive knowledge is a truth; though all truths are not a subject of knowledge, except to the omniscient Mind. As formerly remarked, we obtain our knowledge *directly* by Consciousness, Observation, Experiment, and Testimony; *indirectly* by Reasoning. How far Intuition deserves to be considered as another source of direct knowledge, is questionable. By Consciousness we *know* our mental emotions—we know it to be true that we are angry, or alarmed, or grateful, as the case may be; by Observation, Experiment, and Testimony, we are made acquainted with facts or truths external to our own sensations. It is generally supposed that by Intuition we know *some* elementary truths, as that "a whole is equal to all its parts," that "things which are equal to the same thing are equal to one another," &c.

Some philosophers assert, however, that the knowledge of even such truths as these, is not intuitive but acquired. Mr. Mill, for example, affirms with reference to mathematical axioms, that they are "but a class, the highest class of inductions from experience—the simplest and easiest cases of generalization from the facts furnished to us by our senses or by our internal consciousness." Again, he says, "while the axioms of the demonstrative sciences thus appeared [from his previous reasonings] to be experimental truths, the definitions, as they are correctly called, of those sciences, were found by us to be generalizations from experience which are not even, accurately speaking, truths."

This statement must appear paradoxical to those who are accustomed to regard the demonstrative sciences as being the very quintessence of absolute truth. "What is truth?" may appear a reasonable question if it is not to be found in the axioms, definitions, and demonstrations of the mathematics. Mr. Mill, however, affirms that no such thing exists, or can be conceived to exist, as a real mathematical point or line, &c., and hence infers that the whole science of geometry is founded in hypothesis; while, as we have seen, he affirms that the axioms and postulates, instead of being matters of intuitive knowledge, are founded on the simplest inductions of experience in early childhood. We confess that we have strong doubts as to the force of the reasoning by which Mr. Mill professes to establish these conclusions. Although there is no such thing in nature as a mathematical line (length without breadth), and no such thing as a mathematical point, (having neither length, breadth, nor thickness,) yet we are disposed to maintain that these may be conceived by the mind, just as we conceive the existence of any other abstractions. We affirm, also, that a person who was born blind, and consequently never saw a line drawn, would merely require to have the nature of a

straight line explained to him, (as being the shortest distance between two points,) to perceive and acknowledge the truth of the axiom, that two straight lines cannot enclose a space.

It is true, however (as Mr. Mill does not forget to urge), that all the mathematical axioms, whether they be really intuitive truths or not, may be derived from experience; or may at least be affirmed with some plausibility of reasoning to be so derived; and therefore, as the question is more metaphysical than logical, we shall allow the reader to consider and decide the point for himself. We shall only remark, that, if the axioms of Geometry be not intuitive truths, but acquired or experimental, then it may be truly said that all the mathematical sciences, though chiefly deductive in their demonstrations, are founded, like other sciences, on certain comprehensive principles resting on a series of inductions.

On this supposition, we proceed to the discovery of truth, in even the strictly demonstrative sciences, by arguments derived in the first place from certain inductions. Along with these inductions, however, there must be some intuitive principle, or something that is taken for granted at least, to constitute the major premiss of the argument derived from the first induction. One intuition is therefore indispensable; for if we suppose that the axioms, or other truths generally termed self-evident, are mere conclusions from induction, these conclusions must be drawn by an argument, that is to say by a syllogism, one of the premisses of which is *the induction*, and the other is *a general principle*, which, in the first induction of all, must either be some intuitive truth, or something that is simply taken for granted. We cannot accept the latter hypothesis, and therefore we are forced to the conclusion that there is at least *one intuitive principle*—that which consists in a conviction of the uniformity of nature.

Whether the axioms are direct intuitions or are conclusions from induction combined with this general principle, is not of very great importance. Their truth is obvious to a child as soon as stated. They command immediate, unqualified assent, and this is sufficient. They are few in number, and yet upon these is constructed the whole system of mathematical science. From these as general principles, lying as it were upon the surface, we begin at once the work of deduction, and reason our way downward to the very depths of science, seeking and requiring no other data, no other principles to assist us.

The whole system of Geometry, for instance, may be conceived to be wrapped up in the axioms, postulates, and definitions. The definitions supply the materials of the science, or subject-matter of the reasoning; the postulates and axioms are the principles on which the reasoning is founded—the original premisses from which its truths are deduced by a series of arguments or syllogisms. The propositions are conclusions from the premisses, but, as in every other *train of reasoning*, each of these propositions or conclusions may be employed as a premiss in establishing those that follow. Now, we have seen that in every syllogism, that is to say, in every valid argument, the premisses always involve the conclusion. Therefore, the original premisses, namely, the axioms and postulates, simple and obvious as they are, even to a mere child's comprehension, really involve the entire system of geometrical truth. All the demonstrations of Geometry are merely a successive syllogistic development of truths *implied* in the axioms, when brought to bear on the relations and magnitudes expressed in the definitions.

The discovery of truth by the pure mathematics is, therefore, as nearly as possible, a process of close consecutive reasoning from some very obvious principles, few in number, and which, if not really intuitive, are founded on generalizations from inductions which must have been made in our childhood, and which have become to be accepted by the mind as equivalent to inductive truths. For all the truths of the pure mathematics, beyond the elementary axioms (which are obvious to the meanest capacity), we are indebted to the process of deductive reasoning. No Induction is required to begin with; the general principles, as already stated, lie on the surface; or, if they are really the results of induction, as Mr. Mill would have us to believe, we are unconscious of the process, To all intents and purposes, therefore, the discovery of truth by the pure mathematics is simply a process of Deductive Reasoning from certain intuitive principles furnished ready to our hand.

In the mixed mathematics or mechanical sciences, we have the same intuitive truths, or what may be termed unconscious inductions, to start from as general principles. All the propositions of the pure mathematics which have been deduced from these, may likewise be assumed as premisses in prosecuting this new inquiry. But some additional *principles* are here required. We cannot, from the data of the pure mathematics alone, commence the work of deduction in the mixed or mechanical sciences. We now require to be acquainted with the first or elementary laws of forces, &c., to serve as additional premisses, from which to extend our deductive researches into a new field.

In the science of Statics, which treats of the mechanical powers, or of forces *in equilibrio*, the new elementary principles required are exceedingly simple—so much so as almost to seem intuitive—but still they may be safely admitted to be generalizations from inductions. "The subordinate laws of Statics," says the late Professor Jackson of St. Andrew's, in his *Elements of Theoretical Mechanics*, "may be derived by reasoning strictly demonstrative, from a few very obvious and general ones, which as referable to the principle of the sufficient reason, or to familiar and universal experience, we shall state as physical axioms:—Axiom 1. If two equal pressures be applied to the same point, in directions making an angle, their resultant will be a force directed towards the same parts, and will bisect that angle. Axiom 2. The resultant of forces applied to a point will not be affected by the application or removal of forces, under the influence of which, considered separately, that point would be in equilibrio. Axiom 3. If two equal forces, acting towards the same parts, be applied perpendicularly to the extremities of an inflexible straight line, they will be balanced by a force equal to their sum applied to the middle point of the line in an opposite direction; or their resultant is a parallel force equal to their sum, and bisecting the distance between them."

From these three *additional* axioms are deduced all the rules of Theoretical Mechanics which relate to the equilibrium of bodies, including under that head the rules of the five mechanical powers, which constitute every description of machinery composed entirely of solid matter. We say, "from these three *additional* axioms," because we assume along with them as premisses the axioms and the propositions of the pure mathematics. We still continue our inquiries on mathematical principles; but these inquiries are now extended from the mere consideration of abstract number and magnitude, to a combination of these with the action of forces exerted upon solid bodies. We therefore require some new principles, to constitute the data or premisses from which, in conjunction with the premisses already supplied by the sciences of magnitude and number, we may proceed to deduce the subordinate rules which constitute the science of the action of such forces.

The new elementary principles thus required, in extending our researches from the pure mathematics to the first part of Mechanics, are, as we have seen, the three additional axioms above stated. These, when enumerated, appear so simple and obvious as almost, like the twelve geometrical axioms, to be deemed intuitive truths; yet, on reflection, the fact will be generally admitted, that they are conclusions from induction, or familiar experience. Whatever may be said of the axioms of geometry therefore, such as that "things which are double or halves of the same, are equal to one another," &c., we now begin to perceive, as soon as we embark upon Mechanics, that something like Induction is required towards the *discovery* of certain truths, before we can begin to develop, by a process of Deductive Reasoning, the subordinate rules of the science. We feel, for example, that the axioms above stated, although they are exceedingly obvious, yet may be truths which we have really acquired by experience, and which, in the absence of all experience, we might have been disposed to regard as standing in need of confirmation from direct experiment.

Advancing by another step to Dynamics, or the science of bodies in motion, which constitutes the second part of Mechanics, and carrying along with us as premisses the axioms of the pure Mathematics and of Statics, with all the conclusions deduced from them, which constitute the substance of these sciences.

we find that we require some further data, to enable us to extend our reasonings into this department. But no such data or premisses, with reference to the principles or laws of motion, are found to rank among the obvious and familiar truths which are commonly considered intuitive. Or, if we have any intuitive conviction on the subject, it is, that motion in inanimate bodies must always be produced by the agency of some external force, and that when a body is in motion it has alway a tendency to stop, unless the impelling force which caused the motion continues to act. Now, it may be true that motion in inanimate bodies is always produced by the agency of some external force; but this is a truth of which our belief or conviction may be traced to an early experience much more plausibly and probably, perhaps, than to intuition; while, with regard to our supposed intuitive conviction that motion has a tendency to cease of itself, this, were it even true, could only be acquired from experience, which does in reality tend to produce such a conviction. It happens, however, that instead of being true, it is directly the reverse of the truth. An extended and strictly scientific induction has corrected, in this case, the hasty conclusion which was drawn from our common experience, and teaches, as a fact or general principle now universally admitted, that a body being once put in motion, would always continue to move with the same velocity unless it were stopped or retarded by some external force.

Here, therefore, we arrive at a subject of extensive inquiry, in which there is a clear necessity for setting out with Induction, in order to *discover* and *establish* the premisses from which we are to reason down by Deduction to the subordinate rules of the science. "The phenomena of nature," says the late Dr. Jackson, "even when considered merely as phenomena of motion, are, in their complex state, distinct and varied, to an extent that no language could express, and no memory retain; but, when they have been successfully analysed, such resemblances are detected among the principles, or least complex assemblages, that they can be arranged under a few general heads; and as resemblances detected amidst variety, especially when extensively prevalent are naturally, and even necessarily ascribed to some presiding influence, and considered as the result of regulation, the generalized expressions of what observation and experiment have discovered in the composition and consecutive order of past events, considered as indications of superintending intelligence, and declarations of what is yet to be, are, in the language of Philosophy, denominated Laws of Nature. Those that fall to be particularly considered in this branch of mechanical philosophy [Dynamics], are the laws of Motion. The most general [*i. e.* the *summa genera*] of these, as laid down by Sir Isaac Newton in his *Principia*, are three:—1. Every body continues, when at rest, in a state of rest, and when in motion, in a state of uniform and rectilineal motion, unless it be affected by some force impressed. 2. Change of motion is always proportional to the motive force impressed, and is made in the direction of that force. 3. There is always a reaction equal and contrary to action; or the actions of bodies are mutual, equal, and opposite.—Though these laws are few and simple, they are of most extensive application, reaching from the phenomena that we regard as the most familiar, to that sublime elevation of science from which the disciple of Newton contemplates with admiration, in the order of mechanical connection and harmonious dependence, the magnificent machinery of the solar system."

These laws of motion, though not self-evident—though even conflicting in one point with common experience, because we have no opportunity of ever observing a body in motion that does not meet with some resistance—are easily established by experiment, united with inductive *reasoning* from observed phenomena. It was, however, some thousand years before they were conclusively established by this inductive process. Even so late as in the time of Descartes, philosophers could not conceive that the planetary bodies might continue in motion without the sustained operation of some impelling force; and hence the system of material vortices invented by Descartes himself to account for the sidereal revolutions. But now that the laws have been really discovered, and demonstrated by arguments derived from Induction, a few illustrations are considered sufficient to convey a conviction of their truth to the mind, and the principal portion of dynamical science is devoted to demonstrative deductions from these, as axiomatical premisses. The science has now become almost entirely deductive. Still, from the undoubted discovery, by Induction, of the laws which constitute its ultimate premisses, it furnishes a striking illustration of the parts that are respectively performed by Inductive and Deductive reasoning in the sciences generally.

Hydrostatics, Hydrodynamics, Pneumatics, Optics, Acoustics, Astronomy, are all in like manner sciences based on the pure mathematics as premisses, to which must be added in each department a few additional premisses as axioms, expressive of those leading properties of matter which specially fall to be considered under that department. A certain order may likewise be observed in their elucidation, by which, as we proceed from the one to the other, the conclusions established in each may be rendered available as further premisses (when such are required) in working out the deductions of those departments that follow, instead of ascending in every case to elementary principles. Attempts have been made to unfold the natural order of all the sciences, contemplated in this point of view, so as to exhibit the whole of scientific truth in what may be termed a pyramidal structure of logical reasoning; but this is a subject to which we shall revert in the sequel.

Continuing to confine our attention, in the meantime, to the physical sciences, we find that, when we leave behind us those properties of matter which admit of mathematical investigation —which do, in fact, consist of deductions from a mixture of physical and mathematical premisses, and therefore are not inappropriately termed the "mixed mathematics,"—we move into a field of investigation in which, in the present state of science, the inductive method must preponderate. Chemistry is still a science of experiment; Geology, Meteorology, and Natural History, are still sciences of observation. The great preliminary work of endeavouring, by a wide induction of facts, to discover and demonstrate general principles, from which, as from the axioms of the mathematics, all the phenomena of nature which fall within the province of these sciences may be deductively explained, is still in progress. Such principles, once discovered, supply us not only with an explanation, but even with a certain power of prediction—a fact remarkably illustrated in that infallible certainty and perfect accuracy with which the eclipses of the sun and moon, and other sideral phenomena, are now predicted by astronomers. The fact that, with regard to the state of the atmosphere, we cannot predict the weather or the wind for an hour together, shows that in the science of meteorology all the inductions hitherto made have been inadequate, or that we have failed at least to elicit from those which have been made, any satisfactory general laws by which we can establish the science upon a deductive basis. In Meteorology, in short, we are still without any of those axioms, which, in the pure and mixed mathematics, lie so obvious and ready to our hand that we consider them almost intuitive. The theory of dew has been fully established by one of the finest inductions on record; and Reid's law of storms, likewise confirmed, to a certain extent, by a pretty extensive induction, constitutes the nearest approach that has yet been made in this department of science to a general law; but still, from the vastness, complexity, mobility, and subtle nature of the elements and agents which form the subjects of inquiry, it offers unusual obstacles to progress, and still remains in the infantile stage of induction; the premisses have yet to be established from which we can deduce the rules by which to explain its phenomena. Chemistry is much farther advanced; by a vast and voluminous induction, a number of the general laws have been discovered which regulate the combination and mutual action of bodies; and Dalton's theory of definite proportions, the widest generalization yet achieved in the science, enables us even to *predict* the proportions in which bodies will combine *universally*, as soon as we know the proportion in which they combine *in one case.* In Geology, also, and in Natural History, a vast accumulation of facts has been brought together and classified; important laws have been discovered, from which the work of deduction has commenced, in some cases not unsuccessfully; but still there is much to be accomplished by

more extended researches, and further and higher generalizations from Inductions, before we can rank Geology, or Chemistry, or Natural History, among the Deductive sciences.

The principal instruments of progress in these sciences, at present, are observation and experiment, including, of course, testimony, which may be regarded as representing the experiments and observations of others. These, however, merely furnish us with facts, among which it is our object to discover resemblances, so as to detect the operation of some general law. It is the detection of such resemblances in facts or phenomena apparently different, and wherein the points of resemblance or analogy had formerly escaped observation, that constitutes the key to generalization, and therefore may be termed the secret of inductive discovery. The mere detection of such a resemblance can scarcely be termed a process of reasoning. It seems to be an act of the judgment; sometimes it appears to be accidental, or rather to depend upon a happy combination of imagination and judgment peculiar to original scientific minds. But when the resemblance is detected, the law of which it gives an indication must be established by a process of inductive reasoning.

NEW TRUTHS.

Such a law, so discovered and established, is a *new truth.* The Gravitation of the Heavenly Bodies, when first discovered and demonstrated by Newton, was a new truth; the law of storms, the law of definite proportions, the existence of latent heat (so far as these are really established), are new truths. The existence of America, when first discovered, was a new truth. Each of these facts expresses the existence of a truth which was not previously known, and therefore they are evidently *new.*

"Whether it is by a process of reasoning," says Whately, "that new truths are brought to light, is a question which *seems to be decided in the negative* by what has been already said [in his treatise on Logic]; though many eminent writers seem to have taken for granted the affirmative. It is, perhaps, in a great measure, a dispute concerning the use of words; but it is not, for that reason, either uninteresting or unimportant; since an inaccurate use of language may often, in matters of science, lead to confusion of thought, and to erroneous conclusions."

Now, assuming that the question is not unimportant, we cannot agree with Whately in affirming, that a truth which has been brought to light by a process of Reasoning cannot properly be termed a new truth. It is true he adds—"In maintaining the negative side of the above question, three things are to be premised: first, that it is not contended that discoveries of any kind of truth beyond what actually falls under the senses, can be made (or at least are usually made) *without* Reasoning; only that Reasoning is not the *whole* of the process, nor the whole of that which is important therein; secondly, that Reasoning shall be taken in the sense, not of *every* exercise of the Reason, but of *Argumentation,* in which we have all along used it, and in which it has been defined by all the logical writers, *viz.*, 'from certain granted propositions to infer another proposition as the consequence of them;' thirdly, that by a 'New Truth' be understood, something neither expressly nor virtually asserted before,—not implied (involved) in anything already known. To prove, then, this point demonstratively, becomes, on these data, perfectly easy; for since all reasoning (in the sense above defined) may be resolved into Syllogisms, and since even the objectors to Logic make it a subject of complaint, that in a Syllogism the Premisses do virtually assert the conclusion, it follows at once that no New Truth (as above defined) can be elicited by any process of Reasoning."

This demonstration is, as the Archbishop says, perfectly easy and conclusive *on these data.* Assuming as correct his own definition of a new truth, namely, that it is "something not implied (or *involved*) in anything already known," it certainly follows that a new truth cannot be elicited by Reasoning. But we must take the liberty to question the correctness of his definition, which is indeed a simple assumption of the whole question. All the conclusions of mathematics are, by the Archbishop's own admission, implied or involved in the axioms or definitions; yet it would surely be a gross perversion of language to say, that when Pythagoras announced the Forty-seventh Proposition of Euclid, he did not announce a new truth. The truth was as new to the world when first announced, and is still as new and surprising to the person who hears it for the first time, as was the existence of America when first announced by Columbus. The gravitation of the heavenly bodies, though discovered by a process of Reasoning, was surely the discovery of a new truth in the highest sense of the words. Indeed, if we assume that nothing is a new truth which can be discovered by reasoning from truths that are already known, we cannot be positively sure of the existence of any new truths whatever. As science is advanced, and becomes more and more deductive, truths which are now ascertained only by experiment or observation, and which, therefore, Archbishop Whately would term new truths, may be discovered to be necessary consequences capable of being demonstrated from truths that are known. All the operations of nature are a chain of causes and effects. When our knowledge of the principles of these is more extended, we may be able to demonstrate by strictly logical reasoning from obvious truths, things which are at present known to us, or may be afterwards made known to us only through the medium of the senses or the evidence of others.

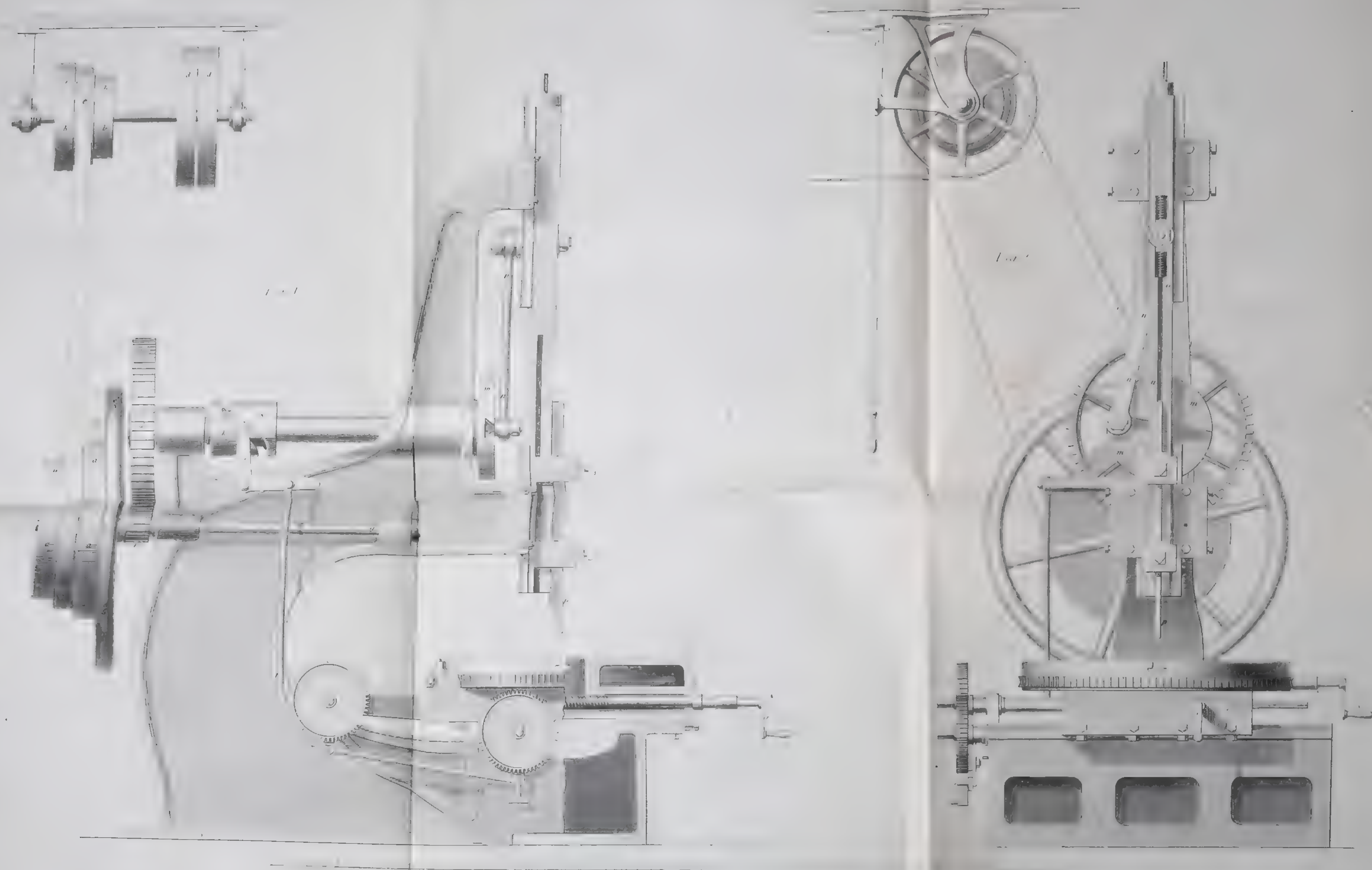
"An able man," says Whately, "may, by patient reasoning, attain any amount of mathematical truths; because these are all implied in the definitions. But no degree of labour and ability would give him the knowledge, by "*Reasoning*" *alone,* of what has taken place in some foreign country; nor would enable him to know, if he had never seen or heard of the experiments, what would become of a spoonful of salt or a spoonful of chalk if put into water, or what would be the appearance of a ray of light when passed through a prism.

This may be true in the present state of science; but when the principles of chemistry come to be better known—when it becomes like mathematics a deductive science—we hold that a person who had never seen a spoonful of salt or of chalk put into water, may really be enabled to foretell what would become of them in that case. All that he might then require would be a knowledge of the principles of chemistry, as these may yet be enunciated, just as "an able man" at present requires a knowledge of the axioms and definitions to work out the truths of mathematics. The latter, indeed, are remarkably simple and obvious, but so may the principles of chemistry be found when these are discovered. The same may be affirmed with reference to a ray of light passed through a prism; but to enable a person to discover, by reasoning alone, what has taken place in a foreign country, implies a knowledge of *data* of which the Archbishop says nothing. Now, to a person who is ignorant of the data of a science, or who does not perceive the connection between the data and the truths enunciated, these truths are not less truly new than some unexpected account of a battle in a foreign country.

In consistence with his views on this subject, Archbishop Whately distinguishes between *Information* and *Instruction.* The communication of that kind of knowledge which he terms *new truths* "is most usually and most strictly," he says, "called *information;* we gain it from *observation* and from *testimony.*" The communication of that which may be elicited by reasoning, and consequently is implied in that which we already know—which we assent to on that ground, and not from observation or testimony, he terms *instruction.* "I speak of the usual practice," he says; "for it would be going too far to pretend that writers are uniform and consistent in the use of these or of any other term. We say that the historian gives us *information* respecting past times; the traveller respecting foreign countries: on the other hand, the mathematician gives instruction in the principles of his science; the moralist *instructs* us in our duties," &c. This is an obvious and common distinction in the use of these words, to which, as far as the examples go, we entirely assent; but then, let the fact be clearly understood that the word *instruction* implies conveying a knowledge, not merely of things *demonstrable,* but of things *demonstrated* by reasoning. A person may receive *information* of the truths or

SLOTTING MACHINE FOR 7 FEET WHEELS,

BY SHARP STEWART & Co MANCHESTER



conclusions of mathematics, which Archbishop Whately will not acknowledge to be new truths; but he does not receive *instruction* in mathematics unless he is taught the principles and reasonings on which the conclusions depend. A person is *instructed* when he is led on from one point to another, with the assent of his judgment or reasoning, perceiving the connection as he proceeds; he may be in this manner even instructed in history; the word is applied with perfect propriety to every systematic method of conveying knowledge. On the other hand, a person who is utterly ignorant of the mathematics may be *informed* of the truths enunciated in that science; and this will be not less truly *information*, though he should be previously acquainted with the axioms and definitions, unless he should be further instructed so as to perceive the connection between the communicated truths and the data.

Instruction, therefore, consists in communicating knowledge *of any kind* systematically; *information* is the mere communication of knowledge *of any kind* without regard to system.

What has been said by us on this subject leads to the manifest conclusion, that there is in reality no essential distinction between the new truths discovered by reasoning and those discovered by the sources of direct knowledge—consciousness, observation, experiment, and credible testimony. Some sensation or emotion of which we are *conscious* for the first time, is the discovery of a new truth. So is the *perception* of anything, by one of our corporeal senses, which we have never perceived before; and this may be conveyed to us either by simple *observation* or *experiment*. A new truth may be learned from *testimony*—evidence admitting of every degree of credibility. So may a new truth be discovered by *reasoning;* that is to say, we may reason from premisses with which we are perfectly familiar, such as the axioms of geometry, to new and unexpected relations which never occurred to us before. To say, with Whately, that these are not new truths because they are implied in the axioms, appears to us highly unphilosophical, and quite unworthy of the logical acuteness for which that eminent writer is distinguished.

This is not entirely a dispute about the meaning of words, because the very use of the words *with a distinction*, implies the belief in a distinction which does not exist. Many truths which, on Whately's hypothesis, would, in the present state of science, be considered *new*, may in a few years be found to follow, as logical conclusions, from *facts* with which we are perfectly familiar at this moment, although we have hitherto failed to discover the connection between them. The definitions and axioms of geometry were long familiar to the world before Pythagoras discovered that the squares of the sides of a right-angled triangle are equal to the square of the hypothenuse. This discovery might have been made by experiment; it might have been effected by exact measurement. In that case it would have been a new truth, even on Whately's hypothesis. Surely it did not cease to be a new truth when it was announced by Pythagoras to follow as a necessary consequence from certain definitions and axioms which everybody knew already.

In like manner, even truths the most *isolated*, so far as present appearances extend—truths which at present we cannot account for—may yet be traced to a logical connection with premisses with which we are perfectly familiar. This is nothing less, indeed, than the aim and tendency of all the sciences. Nature, as we previously remarked, is a chain of causes and effects; all its phenomena are linked together, either immediately or more remotely, either by seen or unseen relations. Science is continually labouring to trace out and render visible the *unseen* relations and agencies. But these are all-pervading in nature; they mingle with, and act upon, each other; there is no such thing as isolation among them; they constitute parts of one great system, which all the sciences combine to explain, and therefore in the sciences also there is no isolation. As all the sciences relate to the same universe, they must be connected together by a chain of reasoning, just as the universe itself is connected by a chain of causes. Hence, in the discovery of truth, we proceed from the one science to the other, using our successive conclusions in each to serve us as premisses or *data* in those that follow. Thus, the whole system of the sciences is not a series of detached arguments, or different and isolated trains of reasoning; but it is *one great train of reasoning*, ascending from the simplest axioms and most familiar truths, to the problem of predicting an eclipse, discovering an unseen planet, or tracing the mysterious course of a comet.

Here, therefore, we conclude our task. Logic, as explained in the preceding chapters, is the science of reasoning. Logic, therefore, is the guide which, in pursuing this *train of reasoning*, must carry the torch through the universe.

SLOTTING MACHINE FOR SEVEN FEET WHEELS.

BY SHARP, STEWART, AND CO., MANCHESTER.

We have already illustrated so many forms of mechanism in this department, and described their peculiarities of movements, that we have little more to do now than give a literal reference to the plates, the drawings in which are so explicit that further description is not desiderated. The cone or speed pulleys are at *a a*, *b b*; the shaft of the lesser being hung by the "gallows," *e e*. The belt, *d*, from the prime mover is moved from the fast to the loose pulley, *d′*, and *vice versa*, by the lever, *f*, *f*, fig. 2. The motion of *b b* is communicated to the slotting machine driving pulleys by the belt, *c c*; *g g*, the fly-wheel in the shaft, *g′ g′*, with the pinion, *h*, taking into the wheel, *i i* on the main shaft, *j j*. The stroke of the connecting rod, *n n*, and cutting tool, *p*, is made less or greater by moving the pin in the lower eye of connecting rod, in the slot in the face of the wheel, *m m*, so as to be nearer to or further from the centre, *b c*, the vertical slide and tool holders. The table is moved by two sets of transverse slides, actuated by the levers, *r r*, *s s*, and is provided with a worm wheel for circular work. The self-acting transverse and circular movements of the table are produced by the mechanism, *k k*, *l l*.

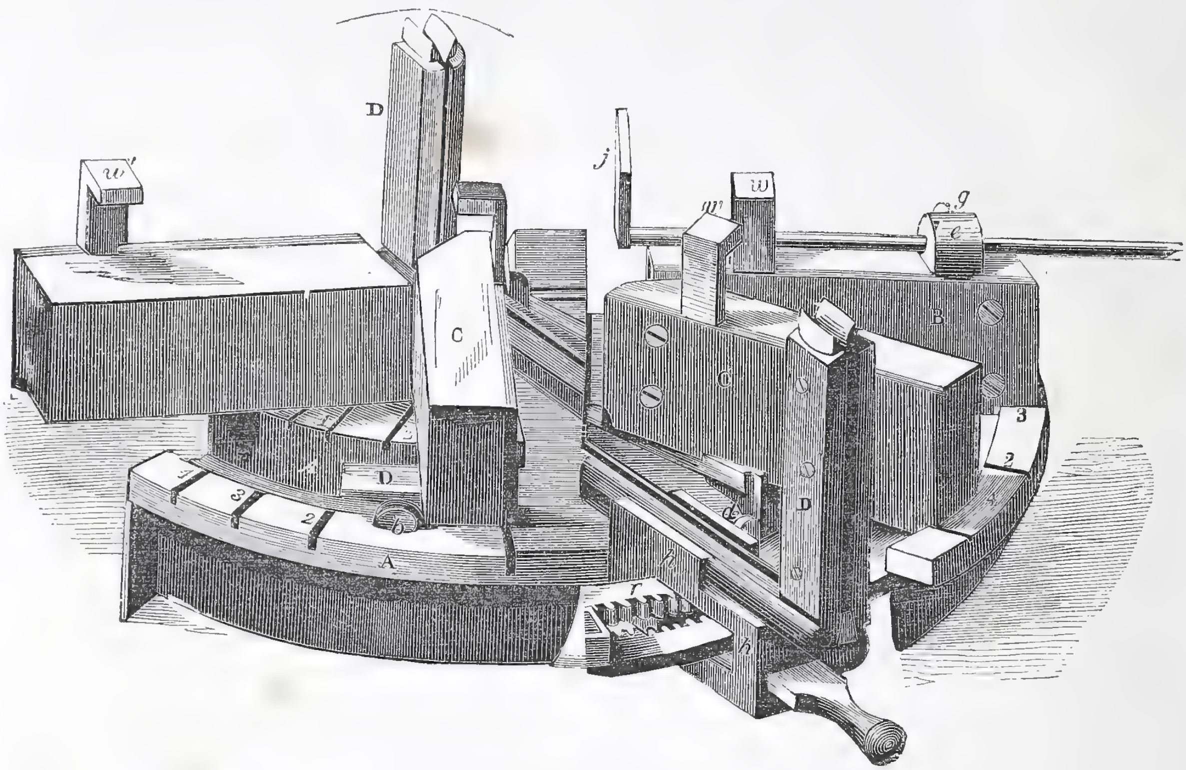
IMPROVEMENT IN MITRE BOXES.

The annexed engraving is a perspective view of a new mitre box, for which an American patent was granted to Matthew Spears, on the 16th of May, 1854.

A A are two supporters of a quadrant form, with a number of grooves or slots in their faces, running at different angles to receive the flanges of the rests. These two supporters are like wings, and can be drawn closer together or further apart for their work; B B and C C are four rests. Their bottom flanges fit into the grooves 1, 2, 3, 4, 5, 6, 7, inclusive, in each supporter, A. The wedges, *w′ w′ w w*, with clamp heads, pass down through an opening in each rest, and fasten them in the grooves of the supporters. D D D represent the saw guide; it can swing to each side, as shown by the dotted line, *d′*, to allow of a bevel edge being cut on stuff. The thumb screw, *d*, binds the axis of the saw guide in its box, *h h*. The supports have two thin metal racks, *r r*, connected to them by set screws in a countersunk channel. They are curved and run under the box, *h h*, of the axis of the saw guide, where there is a small pinion between the racks, which separates them and allows them to be moved from side to side. The wedge, *f*, is for binding them. Each support or stuff platform, A, is capable of being moved out like a wing, to expand or contract the box for the working of different stuffs. The rod, *i*, running through an eye on the top of one of the rests, can be fixed in by the set screw, *g*, or taken out at pleasure. It is a gauge measure to cut stuff to any length, and used in the machine with that rest. The stuff to be mitred is laid between the rests and against them on the face of supports. If there was a piece of stuff shown in the box to be mitred, it would cover the axis, D, of the saw guide, and lie on it. All the rests are not always required in the mitre box as now shown, but sometimes they are all used according to the work to be done. The rests, B B, are placed in the slots, 1, 1, for sawing smaller angles than the edges of the supporters, A A, make with one another when closed. Slots, 2, 2 and 7, 7, are used with the rests in mitring for an angle and its supplement, without altering the machine, only once setting. Slots, 3, 3, are used in

mitering wide or large lumber by opening out the supports wide to a straight line, and tipping the saw guide down till it touches one of the supports. Slots 4, 4, are used when the machine is closed to mitre for a right angle. Slots 5, 5, are used in cutting stuff to any angle to which the machine is set. Slots 6, 6, are used when the machine is closed for sawing lumber for a right angle or square.

This mitre box mitres for any angle, and its supplement, by



once setting; it also mitres and cuts for a right angle, and cuts to any angle to which it is set. It mitres to a right angle with the plane surface of the machine. It can saw a felly or any circular stuff at a straight line from the outer edge to the centre of the same circle. It can be set rapidly to mitre to any angle. The rests, it will be understood, fit into all the grooves, and are shifted from one to the other, for the mitering of any kind of stuff. In this figure all the rests are placed on the supports. It will be understood that the one support, A, is just a duplicate of the other, and that they swing or turn an an axis, the cap of which supports the extreme end of the saw guide, D, below d', so that the supports spread out from that axis which is the centre of the circle, described by the edge of the supports. It is not possible to describe all its uses, that is, how to mitre all the different kinds of work which it is capable of performing, by reference to the figure, as the positions of the rests and supports admit of so many changes; but the joiner will obtain a correct idea of the nature and construction of the machine and its adaptability, from the engraving and description.

IMPROVED BEVEL PLANES.

The annexed engravings are a perspective view, fig. 1, and a transverse section, fig. 2, of an improvement in beveling planes, for which a patent was granted to M. J. Wheeler, G. W. Rogers, H. W. Pierce, and M. B. Tidey, of Dundee, New York, on the 4th of July, 1854.

The object of this invention is to plane a double bevel, or, in other words, to plane two faces at any desired angle to each other, and to a third face. The invention consists in attaching the two cutters which are to plane the two faces, to two wings which are both hinged or otherwise attached to the body of the plane, so as to swing round a common axis, and each of which is adjustable and capable of being secured in any position independently of the other, so as to bring and set the faces of the cutters at any angle to each other, or to the fence which is employed to guide the plane.

A is the body of the plane; B B are the wings which contain the cutters, *f f*, and are connected to the under side of the body, A, by a three-flanged hinge, *c c c'*, fig. 2. One flange, *c'*, of this hinge is inserted in the body, A, and secured by screws, *d d*. The screws are secured one to each of the faces of the wings, B B, and all are united by a pin running the whole length of the wings. The wings are shorter than the body, A, and a recess, equal in length to the wings, is cut in each side of the latter, to allow them to lie up close to the sides of it, and bring their faces and the edges of their cutters as nearly as is desirable in the same plane. The cutters are of the usual form, and secured in the wings by wedges, O O, in the usual way. The wings swing within a bar, D, which is in the form of part of a circle described from the axis, and are secured in any position by means of set screws, E E, passing through slots in the bar, D, and screwing into their backs. The upper surface of the bar, D, is graduated in degrees, commencing in both directions from the sides of the body, A, in order to enable the faces of the wings to be set at any desired angle; F is the fence having the screws, G G, firmly attached to it, perpendicularly to its face; said screws pass through holes in the body, and being furnished on one side thereof with a nut, H, and on the other side with a follower, I, to adjust the fence to the body and wings, for the purpose of planing stuff of various widths; K is the depth gauge, which is adjusted by means of the screws, L M, for the purpose of enabling the tool to cut to the required depth to perfect the bevel, and no further.

The operation of the plane can be best explained by illustrating the beveling of a door stile on opposite sides of the channel which receives the panel. The stile, P, is represented in fig. 2. The fence, F, is adjusted by the screws, G G, to bring the depth of gauge to the proper distance from the side of

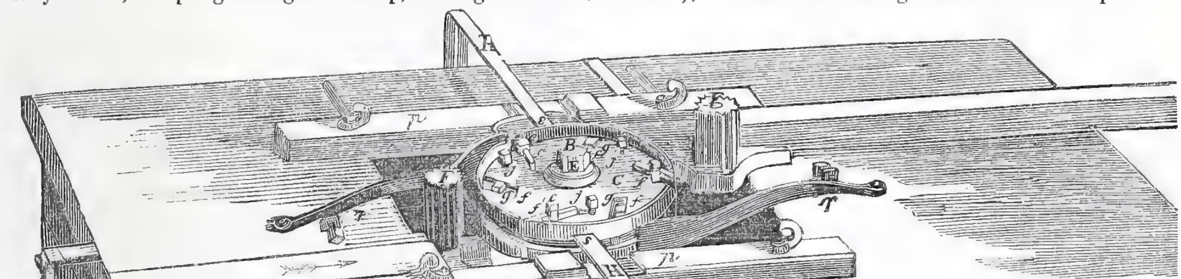
the stile. The wings are adjusted to set the edges of the cutters at the proper angle to each other and to the face of the stile, and the depth gauge is set to the proper depth. The edge of the stile is then planed down till the depth gauge comes in contact with the bottom of the groove. If it be desired, the two sides of the channel may have different bevels, as each wing with its cutter is adjustable independently of the other. By making the edge of the cutters of this plane of proper form, coves, ovolos, ogees, or mouldings of any other form may be produced on the edges of the stuff.

MORSE'S DOUBLE-ACTING SASH AND MOULDING MILL.

THE accompanying engraving is a perspective view of an improved machine for sticking sash, blind slats, &c., for which a patent was granted to C. B. Morse, of New York, in January last.

The figure represents a machine as it stands in the factory ready for use, excepting having on the cap, it being removed to show the interior of the cutter-head. The object of this machine is to cut mouldings on two separate pieces of stuff at the same time with *one* cutter-head, thereby finishing sash bars, mountings, blind slats, &c., before leaving the machine —one piece passing the cutter-head to the right, and the other to the left, simultaneously; the machine in this manner doing double the quantity of work of machines heretofore employed for the same purpose, without extra expense, and work of a superior quality, as the moulding on each side of a piece is an exact duplicate of the other.

A is the top of the machine. When in operation the cap covers the machinery of the cutter-head, prevents all danger to the attendant, and conducts chips under the machine through an opening, so that they are never scattered about the shop; B is a vertical shaft, having its bearing in a transverse cross-piece on the upper part of the frame, and its foot in a cross-piece under the table; C is the cutter-stock upon the upper end of shaft B. It is formed of two flanged discs, so constructed, that while they are made adjustable to accommodate different thicknesses of sash stuff, there will, by its rotation, be a partial vacuum created in its interior (the cutter-stock), and the inward draught thus formed will pass the



edge of the cutters, and remove the shavings from them as soon as formed, and thus admit of the cutters acting twice during each revolution of the cutter-head, without clogging or injuring the stuff; *g g* are slots through the upper disc, to allow the cutters, *f f f*, which are attached to the lower disc, to project up behind the flange of the slotted disc, so as to present a cutting edge over the whole space which is made by the opening or closing of the discs; *j j* are set screws to open or close the disc, in combination with the tightening nut, E, on the cutter-shaft, B; F F are feed rollers, having their upper bearings in the frame, and their lower ends in the cross-piece under the same; D D are adjustable shields placed in grooves in the top between the feed rollers and cutter-head. They form mouth-pieces to the cutters, and prevent the feed rollers from lifting the stuff when passing over the ends of it; *p p* are guides to conduct the stuff through the machine; *r r* are springs resting against the moulding on each side of the cutter head; H H are springs placed opposite one another, and press upon the side of the stuff, holding it down to the bed and the exact cutting point, *s*.

Motion is communicated to the feed rollers by belting passing over pulleys, G G, from pulleys on the small vertical shaft that receives rapid motion by gearing from the main shaft on the end of the machine. The top of the machine is raised and lowered by the crank-handle shown above the driving pulley; from the latter there passes the belt that

drives the cutter shaft, B. The machine is exceedingly compact, and embraces two valuable improvements secured by as many claims, viz., the construction and combination of the discs and cutters described, to produce an inward current, thereby causing the instant freeing of the shavings from the cutters, and allowing them to act twice on two separate pieces of stuff, as shown, during one revolution of the cutter-shaft, also the adjustable shields, D D, in combination with the feed rollers, for the purpose specified.

Mr. Morse has devoted his attention to improvements in such wood-cutting machines for a number of years, and has great practical experience in operating them; he is therefore well acquainted with their defects, and the remedies required to make them more perfect in all their details.

CHEMICAL MANUFACTURES.

CHAPTER VII.

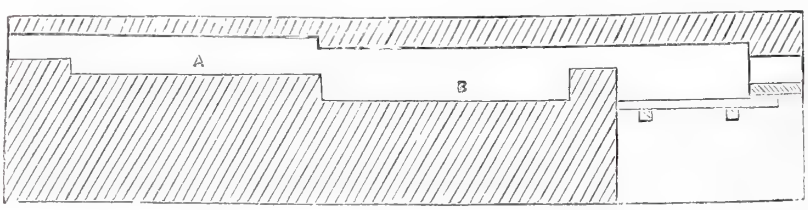
THE MANUFACTURE OF SODA.

The condenser employed, in connection with the furnace described at the end of last chapter, is a square tower of flag stones, filled with large pebbles, a stream of water entering at the top and the gas at the bottom; an opening at the top also communicates with the chimney, and thus creates a slight draught, the current into the chimney from the tower consisting only of atmospheric air with a mere trace of acid. The muriatic acid thus procured, is employed in the production of chlorine for the manufacture of bleaching powder; the acid is mixed with peroxide of manganese in clay retorts heated by steam; the chlorine thus evolved is conveyed into vessels containing slacked lime, which absorbs the chlorine and forms the chloride of lime, or bleaching powder. An engine is employed to move agitators in the chlorine generators, and in the lime chambers, to hasten and perfect the process.

The rationale of the production of chlorine from the mixture of muriatic acid (one atom hydrogen, one atom chlorine) and peroxide of manganese (one atom manganese, two atoms oxygen) is, that one atom of the metal of the peroxide of manganese, seizes one atom of the chlorine of the muriatic acid, to form chloride of manganese, but at the same period of time there are eliminated (from the muriatic acid) one atom of hydrogen, and (from the peroxide of manganese) two atoms of oxygen; the atom of hydrogen instantaneously combines with an atom of oxygen to form the protoxide of hydrogen or water, and the remaining atom of oxygen seizes another atom of hydrogen of the yet undecomposed muriatic acid, and thus forms another atom of water, and liberates an atom of chlorine. Thus, two compound atoms of muriatic acid, and one compound atom of peroxide of manganese, give rise to one compound atom of chloride of manganese, two compound atoms of water, and one single or elementary atom of chlorine.

In M. Gamble's patent process, the sulphuric acid should have the specific gravity of about 1·750; this being higher than that of the acid produced in the vitriol chambers, it requires concentration, but this is effected by the patentee without the aid of any other fuel than the sulphur of pyrites, which is burnt in the process for making the acid. The concentrating pans are placed over the pyrites furnaces and over their flues, and the heat generally lost is found amply sufficient for the purpose. The salt cake made in this manner

Fig. 5.



contains fully 97 per cent. of sulphate of soda, and 4-10ths of one per cent. of oxide of iron.

The decomposition of the salt cake is effected in the "black-ash" furnace, a common reverberatory furnace with two "beds," one being higher than the other: the proportions of lime, coal, and salt cake, are greatly varied by different manufacturers, each esteeming himself the lucky possessor of the best receipt, the workmen (who all work by the piece) sometimes of themselves adding common salt in order to render the materials easily fluxed, the mixture of sulphate of soda and common salt melting at a considerably lower heat than either salt alone: this is a part of a series of similar phenomena observed by Berthollet, and, however scientific, is, of course, prohibited by the masters, as the common salt lessens the value of the product. Fig. 5 is a section of a black-ash furnace; the materials are placed first on the bed, A, and are removed thence and fluxed on the bed, B, during which operation much inflammable gas is extricated, which ignites in jets or "candles" on the surface; the mass is melted and well worked with an oar or paddle, and is then withdrawn into iron moulds, where it solidifies. When cold, the black ash is broken in pieces, and all the soluble matters are extracted by warm (not hot) water, the solution being evaporated by flames playing over the surface: if the heat was applied at the bottom of the vessel, the saline substances would sink as the water evaporated, and would adhere together, retaining water in the interstices, which being suddenly converted into steam, would blow the contents out of the vessel. Any one trying to evaporate a solution of this kind over a common fire, will soon have proof of the fact.

As the salts fall to the bottom, they are withdrawn by a rake and allowed to drain; they are then heated in a reverberatory furnace, termed the "white-ash" furnace, similar to, but smaller than the black-ash furnace already described, and the manufacture is completed. The solution is sometimes subjected to the action of carbonic acid, as in the patent process of Mr. Shanks: a tower filled with pebbles has a stream of the solution passed through it at the same time with a counter-current of carbonic acid; by this means all the caustic soda, as well as the silicate and aluminate of soda, are converted into the carbonate.

There are several patents for various minutiæ of the manufacture, but the above is the ordinary mode of proceeding. It has always been a consideration amongst inventors to simplify this complicated process, it having been proposed to decompose common salt by the sulphates of iron or magnesia; but these salts are of too difficult formation to render this any improvement. Charles William Scheele, in a paper he contributed to the Memoirs of the Stockholm Academy for 1779, gives some curious experiments on the decomposition of common salt and sulphate of soda, which researches at that time attracted the earnest attention of philosophers: he found that a plate of iron, wetted with a solution of sulphate of soda or common salt, and exposed for a few weeks in a damp place, became covered with an efflorescence of carbonate of soda; and quicklime, slaked with brine and similarly left, also became covered with the same efflorescence. The subject has been frequently revived, and has had much ingenuity bestowed upon it, but still remains somewhat obscure and of no practical value.

Another patent process is that of Messrs. Dyer and Hemming, which consists in decomposing common salt in a solu-

tion of bicarbonate of ammonia, the result being bicarbonate of soda and salamoniac (muriate of ammonia); the former substance is converted into the carbonate by roasting, and the latter sold as salamoniac, or reconverted into the carbonate of chalk: so that the process (*theoretically*) is continued by the mere expenditure of chalk, or limestone and salt. A recent attempt to revive this plan has been made in Leeds; the article produced was *pure*, but extravagantly high in price.

A method has lately been patented by Mr Longmaid, and worked on a small scale by a company styled the "Plymouth Patent Alkali Company," for the preparation of sulphate of soda, by roasting in a common reverberatory furnace a mixture of sulphur pyrites and common salt, (oxygen is obtained from the air, the chlorine of the salt uniting with the metal of the pyrites to form a chloride, and the sulphur and sodium, by absorbing the oxygen, become converted into sulphate of soda); it is found necessary to employ pyrites containing but little sulphur or otherwise (as pyrites are generally *bi*sulphurets, and it is the sulphurets which are the active substances) to add some metal to combine with the extra equivalent of sulphur; iron pyrites is commonly selected, and oxide of iron added for the above purpose. The sulphate of soda thus made, is concentrated with an immense quantity of oxide of iron, from which it is freed by solution, if required pure; but for the preparation of carbonate of soda, the same gentleman has patented the use of an oxide of iron, for decomposing the sulphate of soda in the "black ash" furnace (in the place of lime, the oxide of calcium) stating that this substitution is effectual, and that the "soda waste" is oxysulphuret of iron, which by roasting with common salt, is again available for the production of sulphate of soda, instead of remaining on the manufacturer's hands a useless and nuisance creating refuse.

A small quantity of this Company's "ash" is occasionally brought *exclusively* into the London market, but little is publicly known as to the profitable result of the plan; it is of somewhat ancient date, and has often been essayed and abandoned—there are probably but few alkali manufacturers who have not tried it. A report on the subject (by two Liverpool gentlemen, who are tolerably well-known to the chemical world, and who are at present engaged in superintending the Company's works at St. Helen's, Lancashire) has been printed for private circulation, and from the source we have derived our principal information respecting this patent; a table in the pamphlet shows a heavy loss of sulphur.

Mr Longmaid has also patented the separation of the chlorine from the metallic chloride formed in the foregoing process, by igniting them in perfectly dry atmospheric air; a metallic oxide is thus formed, and free chlorine is liberated.

Another patent plan is the preparation of silicate of soda by the ignition of an intimate mixture of common salt and sand in the presence of steam, muriatic acid being the bye product.

The last new process is the conversion of common salt into a nitrate of soda, by nitric acid, muriatic acid being liberated, and the consequent conversion of the nitrate into a carbonate of soda, by ignition with limestone or chalk, or into a silicate of soda by ignition with sand, the nitric acid flying off as such, and being condensed in suitable condensers, ready for acting again on common salt; this plan is at present in practice in the neighbourhood of London. The silicate of soda in this and the preceding patent, is either to be decomposed by carbonic acid, or disposed of *per se* to glass makers. We much fear that most of these ingenious plans will be found of little practical service; and there is yet undoubtedly great scope for inventors to exercise their talents in this fascinating branch of scientific manufacture.

Bleaching-powder.—Another curious result of the extensive use of sulphur and common salt in manufactures is the production of *chlorine* and *bleaching-powder*, frequently carried on at the sulphuric acid and soda works. Bleaching-powder is chemically called chloride of lime; but its most marked property has given it the former distinctive name.

Here also we have another example of the influence which legislative matters exert upon chemical manufactures. If the duty had not been taken off common salt, it may be safely averred that the manufacture of these articles would not have reached its present height. Salt not only yields soda from one of its constituents, and muriatic acid from the other, but this acid itself is made to yield chlorine, by separating hydrogen from it. Chlorine is a gas, and as such is not in a convenient form for sale and commercial transit; but by causing it to be absorbed by any dry and cheap substance, such as lime, it can be brought into a convenient form. Such is the case in practice. Chloride of lime is now used to an immense extent in different branches of manufacture, the lime being merely a vehicle for containing the chlorine, and all the remarkable chemical effect being due to the latter.

Chlorine requires for its production or evolution a degree of care in the choice of vessels, analagous to that exhibited in so many other branches of chemical manufacture. The chief vessels employed are made of stone contained withinside iron vessels; and into the innermost vessels are put the necessary ingredients. These are muriatic acid and oxide of manganese. Steam is admitted between the inner and outer vessels, by which the mixture is raised to the required temperature; and by the mutual action of the chemical ingredients they become so altered in their combinations as to produce muriate of manganese, water, and chlorine gas, the last named of which is the object of the manufacture. In this process, and in the subsequent one of causing the chlorine to be absorbed by lime, the most scrupulous precautions are taken to prevent the escape of any of the gas into the open air; since it is so deadly a poison, that the inhalation of a very small portion of it would suffice to take away life. Some years ago, when the muriatic acid gas was allowed to go to waste up the chimneys of sulphuric acid works, chlorine was produced from sulphuric acid, salt, and the oxide of manganese; but the muriatic acid is now economically used instead of the sulphuric acid and the salt—thus at once cheapening the product and saving the atmosphere from contamination.

The mode of impregnating lime with the gas is very curious. A chamber is fitted up in the most completely air-tight manner, with a few openings carefully secured. On shelves in this chamber is deposited slaked lime in powder, spread out so as to allow the chlorine to act upon it. The gas, as it escapes from the vessels, flows through a pipe into this chamber, which it gradually fills; and as soon as it comes in contact with the lime, the two substances unite, forming chloride of lime, by which the whole of the gaseous element is absorbed.

This powerful agent is in a most convenient form for manufactures. When the chloride of lime is immersed in water, it dissolves, and the water becomes impregnated with the chlorine, which then forms the bleaching-liquid now so largely used in the manufacturing districts. About a century ago our manufacturers of linen used to send their cloths to Holland to be bleached, where they were steeped in potash ley, then washed, then steeped in buttermilk, and then laid out on the grass for several months; so that the linen was thus out of the maker's hands for seven or eight months before he could bring it into the market. A process very similar next became established in this country; the goods being still several months under process of bleaching, but the transference to and from Holland being no longer necessary. Next sprang up an improvement by the substitution of sulphuric acid for milk, whereby the same effect was wrought in one day which before occupied six weeks, and brought the whole bleaching process within a period of three or four months. Next ensued the discovery that a particular gas, evolved by the action of manganese on muriatic acid, had the power of destroying vegetable colours, or of bleaching; and about sixty years ago, Berthollet practically applied this new gas (chlorine) in bleaching. Next followed the introduction of this method into England and Scotland, and the institution of experiments for facilitating the use of the gas in bleaching establishments. If used as a gas, the effects were highly deleterious to the

workmen; if absorbed by water, the water gave out a very offensive odour. Potash was added to the chlorine water, to remove the smell; next, the cloth was passed through lime-water previously to the application of the chlorine; and next, Mr. Tennant of Glasgow contrived the means of making a liquid chloride of lime, which was the opening to a field of vast importance. One more step was the devising a mode of producing a *dry* chloride of lime which should be capable of being easily packed in barrels, which should retain all the bleaching properties of the chlorine without its offensive odour, and which should be procurable at a cheap rate. This has been done; and the chloride of lime of modern times is presented to us as one of the most successful instances of chemical science applied to manufactures. Instead of eight months, a period of a few hours only is now necessary for the process of bleaching. Dr. Thomson states, "A bleacher in Lancashire received fourteen hundred pieces of grey muslin on a Tuesday, which on the Thursday immediately following were returned bleached to the manufacturer, at the distance of sixteen miles; and they were packed up and sent off on that very day to a foreign market. The quick return of capital which is thus made is a benefit entirely to be ascribed to the new mode of bleaching."

MANUFACTURE OF WATCHES AND CLOCKS.

The manufacture of these beautiful examples of ingenuity has many points which recommend it to our attention. The surprising extent to which the subdivision of labour has been carried, the value of the manufactured produce, the exquisite accuracy of the workmanship, and the peculiarities connected with the localization of this branch of art—all form interesting subjects for notice. It may be well to glance at the watch-making arrangements of Switzerland, and afterwards at those of Clerkenwell, before treating on the mechanical details of the manufacture.

Dr. Bowring, in a "Report on the Trade and Commerce of Switzerland," presented to parliament a few years ago, gave some curious details concerning the rise of the watch manufacture in that country. It appears that, about the end of the seventeenth century, one of the inhabitants of Neuchatel brought home a pocket-watch from a foreign country which he had visited; it got out of repair, and he gave it to a mechanic named Richard, who not only succeeded in readjusting it, but conceived the idea of making one for himself. After many trials and discomfitures, he succeeded in his object; and the product of his ingenuity excited the astonishment and admiration of all his neighbours: the emulation of others was roused; and by degrees the art of watchmaking became introduced among the mountaineers, who had previously had very little other employment than that of a strictly agricultural character. During the first half century after this new era, a few workmen only were employed in the art, and both the quality and the profit of the manufacture were but small, owing to the want of proper tools and materials, and to various commercial inconveniences under which the workmen laboured. By degrees, however, they succeeded not only in equalling the productions of other countries, but even in excelling them. As the manufacture of a good watch depends largely on the possession of good tools, the manufacturers of Neuchatel came gradually to regard the making of the tools themselves as among the most important parts of their art; and they have ever since had considerable skill in this art.

About the year 1750 a few of the Neuchatel merchants began to collect small parcels of the watches, and carry them to other countries and districts for sale. The system succeeded so well and the demand for Neuchatel watches became so large, that nearly the whole of the inhabitants of the canton entered into the manufacture, in one or other of its numerous branches. The result of this was, that the face of the district underwent a great change: that which had before been rather a barren and bleak mountain district, became studded with well-built villages, connected by easy roads and media of communication, and inhabited by a prosperous population. The upper valleys of Neuchatel formed the germ of this system, from whence it spread to the surrounding cantons. During the winter, which lasts at least half a year in that climate, the inhabitants remain almost wholly within doors, employed in watch-making. It is supposed that, in one or other of the various branches connected with the manufacture, there are twenty thousand persons employed in the district of which Neuchatel is the centre; by whom about eighty or ninety thousand silver watches, and thirty or forty thousand of gold, are made annually. The workmen carry on their labours at their own houses, working for those merchants or wholesale manufacturers who will pay them best: they are mostly landed proprietors on a small scale, cultivating their own ground in leisure hours, and living simply and frugally in the midst of their families.

Geneva is another great centre of the Swiss watch trade; indeed the manufacture has been carried on there for many centuries. The works and machinery are made chiefly in the neighbouring villages, and are sent to Geneva to be put together and finished. Chronometers, time-keepers, clocks, stop-watches, inferior watches, repeating-watches, musical watches, musical boxes, seals, and rings—all are made largely at Geneva, and give rise to an extensive commercial intercourse with other countries. Dr. Bowring takes the following view of the manufacture in relation to similar branches of industry elsewhere:—"A watch formerly had been an object indispensable for its use; it now became an article of taste and fashion; it furnished a convenient token for the expression of regard, and a present combining utility and taste with positive value. Under whatever form and for whatever purpose employed, the use of watches became the cause of unbounded activity in the workshops of Geneva. Many fashionable watches, those of a common description, and those of a still worse class, which sin against all true principles in their construction, those again remarkable for the singularity of their make, are for the most part an assemblage of parts destined to last but a little time, even from the first moment of their being put together, which time the watch-makers still further endeavour to shorten to the utmost of their power. The imperfections of these little machines are a certain warrant of their speedy destruction; besides which, the want of taste, the damage they receive in warehouses through inattentive and unskilful hands, or from a salt and humid atmosphere, all sorts of accidents and want of care on the part of the owners—are further causes which contribute powerfully to the destruction and demand for watches. If to the causes of destruction here mentioned we add the vast new sources of demand arising out of increased civilization, the wider spread of general prosperity, the local industry which pervades every spot, the commerce which penetrates the most remote corners, we shall find in these circumstances abundant reason to anticipate a constantly increasing demand for the watches of Switzerland, which perpetually struggles to maintain its pre-eminence for taste and moderation in price. It may therefore be presumed that this branch of industry contains within it the seeds of a firm and permanent prosperity, and is destined to increase rather than to decline."

The watch trade between Switzerland and France is accompanied by some remarkable features. Almost all those which obtain the name of "French watches," although the movements may be made in Paris, are sent to Switzerland to be made up, and are then returned to Paris. A government duty is imposed on watches crossing the frontier, and this duty has given rise to an extraordinary system of smuggling. Sometimes a hundred or a hundred and fifty watches are sewn into the smuggler's waistcoat. More usually, however, dogs are employed as the smugglers. The dogs are trained to this office, and are conducted in packs to the frontier. They are kept without food for many hours, then beaten and laden, and then dispatched at the beginning of the night; they reach the abodes of their masters, which are generally selected at a distance of two or three leagues from the frontier, as speedily as they can, and are well treated and fed on their arrival. By this mode of proceeding, the dogs are led to exercise all their intelligence to get safely from the place where they are badly treated to

the more welcome and hospitable home. The dogs are often trained to attack the custom-house officers who endeavour to stop them; and the difficulty of knowing how to deal with this crafty system is such, that the French government some years ago offered a reward of three francs for every smuggling-dog killed; and more than forty thousand of these ill-used animals were destroyed in ten years. We believe that changes in the nature or amount of the transit duties have lessened the prevalence of this vicious system.

A short glance at the Clerkenwell manufacture will not now be misplaced. Very little is known concerning the past history of watch-making in this district; but at the present day it is scarcely an exaggeration to say that nearly the whole prosperity and industry of the district are dependent on the making of clocks and watches. The "movements" of a watch, or the wheels contained between the two brass plates, are made almost wholly in Lancashire; but the making of the other parts, and the general adjustment of the whole, are carried on far more largely in Clerkenwell than in any other part of the kingdom, perhaps more largely than in all the other parts taken together. We will abstract from *London* No. 59, a few remarks on the subdivision of the manufacture.

When the "movement" of a watch arrives in London, it is purchased by the "watch-manufacturer," who engages the services of a numerous body of persons to complete the watch from this skeleton. It is to be supplied with the "motion-work" or mechanism in connection with the hands; with a "spring" and connecting mechanism; with an "escapement" or apparatus for insuring the uniform "going" of the watch; with a "case," generally of silver or gold; with a "dial," usually enamelled, but sometimes of chased metal; with a "glass," and with other appendages. The manufacturer gives these various parts to be made by certain persons who undertake definite portions; and these parties further subdivide to a degree of minuteness scarcely credible. The "escapement-maker," for instance, so far from being one workman who manufactures everything relating to an escapement, may be a "duplex-escapement maker," or a "lever-escapement maker," or a "horizontal-escapement maker;" he may also have under him many workmen, each of whom is employed in, and is competent only to the manufacture of, some one particular part of some one kind of escapement. The enamelled dial of the watch, too, instead of being perfected by one man, passes through the hands of several: one man forms the dial out of sheet-copper; another coats it with the beautiful enamel; a third paints the letters and figures in enamel colours, and a fourth adjusts the dial to the other parts of the watch. The "case," in like manner, passes through many hands; for, besides the workman employed in actually making it, there is the "secret-springer," who forms the mechanism by which the two halves of the case close together; the "engine-turner," who engraves those curious devices which ornament the cases of some watches; the "pendant-maker," who constructs the loop and apparatus by which the watch is suspended from the chain, guard, or watch-ribbon. The "hands" of the watch form a branch of the manufacture totally distinct from the others; so does that of the watch-key; and even that of the little "index," by which we regulate the "going" of the watch when too fast or too slow. Some of the wheels of the watch are considered so far distinct as to have their teeth formed by workmen who do not cut the teeth of other wheels. The "fusee," likewise, a conical piece of brass on which the chain is wound by the watch-key from the barrel, is made by one who is wholly employed as a "fusee-cutter." In the "jewelling" of a watch (a term which relates, not to the outward adornment by means of jewels, but to the use of hard gems as a material in which to make pivot-holes for the "movement") some men are employed in preparing the gems, and others in making the pivot-holes.

This kind of dissection might be greatly extended, showing that the subdivision of employments is carried further in this than in any other branch of manufacture. The "watch manufacturer" is a tradesman who understands all these subdivisions, and is, therefore, competent to bring into one whole the labours of all these various classes and subclasses. He is generally a person possessing some considerable capital, as occupying the channel through which the purchaser deals with the actual makers. The watch trade of Clerkenwell does not exhibit large factories where two or three hundred men are working in a body. It exhibits thirty or forty distinct classes of tradesmen, comprising, perhaps, three times that number of minor divisions, all living and working at their own homes, and contributing the various parts to a watch, which is finally completed by the "watch manufacturer." Some of these thirty or forty are men possessing sufficient capital to employ in their workshops a considerable number of workmen, among whom they can carry out the principle of the division of labour to a still greater extent, while others are persons who work at their own homes, taking no more work than they can execute with their own hands, or perhaps with an apprentice.

We may now take up a few of the manufacturing details, especially those relating to large clocks, which have not hitherto been alluded to. The clocks placed in the turrets of churches and large buildings, as being the farthest removed in character, as well as in size, from pocket watches, require to have their prevailing features pointed out.

In the first place, everybody knows that a church clock is generally fixed in the tower, or in some elevated part of the building; and it is also known that many churches exhibit clock-faces or dials in four different directions, so that the hour of the day may be observed by persons on all sides of the church. Now, there are, doubtless, many who entertain the opinion that in such a case there are four clocks, one for each dial or face, and who cannot conceive how all the four hour-hands and the four minute-hands can be moved by one clock. There are also, it is probable, many different opinions as to whether the bell or bells which strike the hour, which chime the quarters, which (in some churches) play a psalm or hymn tune at certain intervals, which are tolled at a funeral, and which are rung at times of rejoicing, are all, or any, struck by the clock itself, or whether by men who act as bell-ringers. It may therefore be as well to state at once, that when a church tower exhibits four clock-faces, all at equal height, and opposite to the four points of the compass, all the hands are moved by the mechanism of one clock, which is placed in the midst of the tower, at equal distance from all the four faces. With respect to the bells, it may be stated that they are hung either over or under the clock, according to the size and general arrangement of the church tower; and that the hour is struck on a bell by a hammer moved by the clock; the quarters by similar mechanism acting on other bells; the psalm or hymn tunes by the action of a rotating barrel similar to those seen in musical snuffboxes; and the tolling and pealing by bell-ringers, who pull ropes connected with the bells.

There is in the eastern part of London a church clock which stands at a greater height from the ground than any other clock, we believe, in or near the metropolis, not even excepting that noted city monitor, St. Paul's clock, and which presents four very large faces on the four sides of the tower. This clock is that of St. Ann's church, Limehouse; and we perhaps cannot do better than make it the text for what we have to offer on this subject.

The value of room in a church tower is such that the approach to the bell-loft and clock-room is generally narrow and awkward to a degree which renders the ascent anything but inviting. The short, narrow, steep, dark, and winding stairs; the loop-holes through which the wind finds entrance in a cutting blast; the small doors and outlets; the dreary loneliness, and no less dreary echo of the footsteps; the cold and the dust—all are familiar to those who have ascended to the upper part of St. Paul's cathedral, and are almost equally observable in other church towers, including the one to which our attention is here directed.

On ascending to a height of about a hundred and thirty feet, in the tower of Limehouse church, we find ourselves in the "clock-room." This is a square room, bounded on the four sides by the thick walls of the tower, and having a wooden flooring on which the clock rests. The light is very limited, and it is not till the eye has become a little accustomed to the

gloom that the objects in the room are discernible. The clock is seen to be enclosed in a wooden case about eight feet high, six feet wide, and four feet deep, the two opposite sides of which may be thrown open by means of folding-doors, thus exhibiting a complicated assemblage of wheel-work and other mechanism within,

The clock contains about thirty wheels, some of which govern the motion of the hands; others, the striking of the bell.

The clock is placed in the centre of the room, and a visitor can walk entirely round it, without interfering in any way with the mechanism connected with the clock-faces visible outside the church. It may then be asked, how are the hands on these faces brought into connection with the moving machinery? We find an answer by observing the arrangements overhead, as we pass round the clock. There is a horizontal bar of wood extending from the clock on each side to the wall opposite to it, and on this bar is placed an iron rod, which is set in rotation by the clock, and, in its turn, causes the hands to rotate round the clock-face on the outside of the tower. There are four of these rods branching out from the clock in a horizontal position towards the four points of the compass, each rod governing the movement of one pair of hands. On looking downwards from the clock-room, we see the mechanism by which the clock is set going, and also that by which the bell is struck every hour. There are neither chimes nor quarter-hour bells at this church, so that the striking machinery connected with the clock has relation only to one bell. Examining a little more closely, we see that the moving power is a heavy iron weight, suspended by a rope which coils round a barrel, and that the instrument which strikes on the bell is an iron hammer connected with a series of levers and rods.

Such are the chief points which become observable in the clock and bell tower of the church here alluded to; and if any other of the metropolitan churches were similarly visited, they would be found to contain the same general parts, modified by the circumstances in which they are placed. Some, in which only one clock-face is required, would not have the four connecting rods branching out horizontally from the clock; others would have the bell and striking machinery above the clock instead of below it; others would be without a wooden case, provided the room were close and free from dust; while others again would have additional striking machinery, for quarters or chimes.

Thus far for the general arrangement; and now we may attend a little to the manufacture and mode of action of these several parts. Not the least remarkable of the circumstances connected with church clocks and bells, is the very narrow limits within which the manufacture is confined. There are, we believe, only two establishments in the metropolis at which church-clocks are made. The cause for this limitation may perhaps be sought in the comparatively small number and long duration of these pieces of mechanism. New churches shoot up but slowly, and old ones do not have a renewal of clocks and bells except at long intervals.

Neither a pocket-watch, nor an eight-day dial, nor a common Dutch clock, will exactly convey an idea of the construction of a church-clock; for, instead of being moved by a spring, as the two former, it is moved by a weight; while, on the other hand, its accurate finish of workmanship is wholly unrepresented in the Dutch clock. Generally speaking, the framework of a church-clock is made of iron, the principal wheels of brass, and some of the pinions and finer work of steel. The arrangements of the maker are therefore regulated according to the number and parts of the clock made at his factory. Whoever has seen a watchmaker at work, must have observed the extreme minuteness of his tools and working apparatus; but such a person is not strictly a *maker* of watches; he only puts together, and adjusts and repairs, the various parts which have been made by many different hands. In the clock-manufacture, and especially in church-clocks, this subdivision of employments is not carried out to nearly so great an extent. At the church-clock factories, almost every part of the mechanism of a church-clock is made within the establishment, except the rough castings in iron and brass. In the smith's shop all the forging and filing of arbors, bars, and other works of iron are effected, as well as the case-hardening of the finished pieces. In the wheel-cutting shop is carried on the beautiful operation by which the teeth of wheels—that important department of all such manufactures as this—are cut. In other shops, the general fashioning and adjustment of the numerous pieces which form a clock are effected, aided by various pieces of mechanism, such as lathes for turning brass, iron, and wood, drills, revolving machinery, polishing apparatus, &c.

Without attending particularly to the classification which a clock-maker would lay down, we will separate a church-clock and its mechanism into five parts—1st, the moving power; 2nd, the "movement," or going wheels; 3rd, the regulation, or pendulum arrangements; 4th, the indication, or mechanism connected with the hands; and 5th, the striking machinery. Any attempt to follow the minute details of clock-making would be quite out of the question, and will not be made here.

First, then, the *power*. Every child knows that the old familiar clock, which has perhaps formed one of the household inmates as far back as he can remember, is "wound up" occasionally, not by turning any wheel or handle, but by elevating an iron weight to the height of the clock; almost every child knows that the little pocket-watch, whose tickings excite such astonishment in his mind, is "wound up" by means of a very small key; but there are many children of larger growth who are utterly at a loss to know what this winding-up really means. The main body of a clock or watch consists of many wheels which work one into another, insomuch that if one wheel moves, the others are drawn into motion by it. But there must be something to impart this motion in the first instance; and this is called the *power*. We know that if the pendulum of a common clock be stopped, the clock is stopped at the same moment; and that the movement of the clock is renewed when the oscillations of the pendulum are renewed. Hence many persons may suppose that the pendulum is the source of the clock's motion. Again, there are stop-watches in which, by moving a little pin, the watch may be made to stop; and then, by a contrary movement, the going of the watch may be renewed; and hence the pin seems to be the source of motion. But both these suppositions are erroneous. In both these cases of stoppage, the rotating wheel-work is checked by a small piece of mechanism, and the motion is renewed when the check is removed; but the *production* of the motion is a totally different affair. In a common pocket-watch, the key by which the winding-up is effected is placed on a small piece of mechanism called a "fusee," from which a chain extends to a brass box or barrel. This barrel contains a fine and highly tempered steel spring, which becomes coiled up very tightly by the rotation of the fusee and the winding on it of the chain from the barrel. This tight coil is so different from the natural state of the spring, that the latter exerts a powerful pulling force in its endeavours to regain its original position; and this force tends to make the barrel in which it is fixed rotate, because by this means only can the original state of the spring be regained. When once the barrel is made to rotate, that rotation can be communicated, by toothed wheels, to other mechanism. Such is the source of power in pocket-watches, in chronometers, and in the dials which are now so much used in public buildings and large apartments.

In church-clocks, turret-clocks, and common house-clocks, there is no such spring as that alluded to in the last paragraph. There is a line or rope, descending perpendicularly from a particular part of the wheelwork, and having an iron weight suspended from its lower extremity. The iron appendage of course exerts a gravitating force in proportion to its weight, and descends gradually; but from its mode of attachment, it cannot do so without causing the rotation of a barrel round which the cord is wound. When the pendulum is stopped, either purposely or accidentally, a catch or detent falls into such a position as to prevent the rotation of the barrel; but this obstruction being removed, the barrel rotates so long as the weight descends; and this rotation is communicated, by toothed wheels, to other mechanism. When the weight descends to the floor, or when all the cord is unwound from the barrel, the clock must stop; but before this time arrives

the machine is wound up by causing the barrel to rotate in an opposite direction, by which the cord becomes re-wound upon it, and the weight elevated.

In a house-clock, the weight is so small that the winding-up is effected easily by pulling a small handle; but in larger clocks the aid of a winch or windlass is required. The length of the cord is proportioned to the diameter of the barrel, and to the time which the clock is intended to "go" between each two windings; and is, in a church-clock, very considerable. At the Limehouse clock, the time of going is, as in most church-clocks, eight days, and the weight by which the barrel is made to rotate amounts to about sixty pounds. The line does not fall perpendicularly from the clock to the weight, but passes over two or three pulleys for economy of space.

2nd. The "*movement*," or the going-train of wheels. The makers of clocks and watches apply the name of the "movement" to the assemblage of wheels which are put in motion by the moving-power. Technically, those wheels which are connected immediately with the hands, with the pendulum, or with the striking machinery, are excluded from this group; but our purpose here is to say a few words respecting the wheelwork generally.

Almost every wheel in a clock has teeth or notches cut in its circumference. Sometimes these teeth stand out radially from the edge; sometimes they are perpendicular to the plane of the wheel; sometimes they nearly resemble the teeth of a saw; but whatever be the varieties, a glance at the interior of a clock or watch will show that almost every one has these indentations in some form or other. This is one of the modes adopted in general mechanism, for communicating motion from one wheel to another; pulleys, straps, and bands, being inconsistent with the minuteness of a clock or watch. In some cases two adjoining wheels work into each other, the teeth of one interlocking in those of the other; but in other cases a small number of teeth are cut in the pinion or axis of one wheel, which work in the teeth at the circumference of the other wheel; and indeed it is in this latter way that a difference of velocity is generally attained. If, for instance, a wheel with fifty teeth work into a pinion of ten teeth, the pinion will rotate five times as fast as the wheel, and thus becomes a source of higher velocity. The great point of attainment in the "movement" of a clock or watch is, that one particular wheel shall rotate exactly once in an hour; this being effected, the arrangement of the hour and minute hands becomes easily determined. The proportions of the teeth in all the wheels and pinions is therefore so fixed as to lead to this rate of movement. In the Limehouse clock, the barrel, which is a solid cylindrical block of elm, about eighteen inches in diameter, is attached at one end to a toothed wheel, about two feet in diameter, which rotates with it; and this rotating wheel forms one in a train which leads to the hourly rotation of one particular wheel.

The manufacture of the "movement" or "going-train" of a clock or watch consists, therefore, principally in the careful preparation of toothed wheels and pinions. These wheels are made sometimes of brass, and in others of gun-metal, while the pinions are of case-hardened steel. The wheels are brought to the clock-factories in a very rough state, just as they are produced by the caster or founder, consisting merely of a circular rim, connected more or less with the central part through which the axis is to pass. The whole manufacture of the wheel from this rude germ is then effected in the shops of the factory. There are lathes for giving to the wheel a perfectly true periphery, by means of sharp steel tools; various pieces of mechanism for shaping, smoothing, and polishing every part of the surface; and, lastly, a very beautiful engine for cutting the teeth.

In these last-mentioned machines, a horizontal rod or bar is made to rotate on its axis with great rapidity; and at one part of its surface is fixed either a wheel or a small sharp piece of steel, corresponding in shape to the teeth about to be cut in the brass wheel. The latter is fixed horizontally on a stand, at such a distance from the cutter that the latter can just reach it in the course of its rotation. The amazing rapidity with which the cutter rotates, enables it to cut through the brass with great ease, the pressure or contact being regulated by a lever, which the workman moves with his right hand. Cutters of various shapes and sizes, but all made of hardened steel, are provided for the cutting of different kinds of teeth. When one tooth is cut, the workman shifts the wheel round a little, to present a new portion of the circumference to the action of the cutter, only one tooth being cut at a time. The extent of this shifting is managed thus:—A brass plate, lying horizontally on the bed of the engine, is marked with a great number of concentric circles, each of which is divided into a number of precisely equal parts, the number being different in the different circles. One circle, for instance, is divided into forty-eight parts, another sixty-four, a third seventy-two, and so on, as may be found most advantageous. If a wheel is to have any number—say sixty-four—teeth in its circumference, a lever is so adjusted that a sharp point at its extremity shall just reach the circle, which is divided into sixty-four parts; and as there is a little hole made in the plate at each of these divisions, the sharp point attached to the end of the lever will drop into all these holes in succession, as the plate revolves. The revolution of the wheel which is to be cut, causes also that of the divided plate, and the workman knows, by the dropping of the sharp point into one of the little holes, when he has shifted round the wheel to a sufficient distance.

No one who has not closely attended to the matter can conceive the difficulty which has been experienced in thus dividing circles into any number of rigorously equal parts. All the resources of art, shown by Ramsden, Troughton, and other eminent mathematical instrument makers, have been required in the division of circles for astronomical instruments; and although such strict accuracy is not required in common clock and watch wheelwork, yet the amount of skill required and shown therein is sufficiently striking,

Whether the teeth be cut in brass, in gun-metal, in iron, or in steel, whether they are in the wheel itself, or in the pinion, and whatever their shape may be, the cutting is effected nearly in the same way, and is succeeded by various finishing and polishing processes requisite for the accuracy of the wheel's motion. Here then we may leave them and proceed to—

3rd. The *indication*, or mechanism connected with the hands. The dial-plate, or rather face of a large church-clock, is generally of wide dimensions, as a means of making its indications conspicuous from below. The four clock-faces at Limehouse church, for example, are each thirteen feet in diameter, with hands and figures of proportionate size. The hands are made of copper and weigh about sixty pounds the pair. Each hand has, at the extremity opposite to the pointed end, a heavy piece of copper sufficient to act as a counterbalance, and to allow the hand to obey the motion of its axis; this counterbalance is generally painted black, to render it less visible. The arrangement of the mechanism connected with the hands, may perhaps be understood from the following description:—At the upper part of the clock is a horizontal wheel, which gives motion to four wheels at right angles to it. These four wheels are connected respectively with the four horizontal rods, which proceed from the clock to the faces. Each of these rods, which are about eight feet long and three-quarters of an inch thick, rotates once in an hour, and communicates that rate of motion to the axis or pinion on which the minute-hand is placed. Other wheel-and-pinion work so modifies this motion as to make another axis rotate once in twelve hours: and on this latter is fixed the hour-hand. It will therefore be seen, that the sole source of the movement of the hands is the rotation of the iron rods, which extend across the clock-room, and that the mechanism of the clock sets these rods revolving.

Of the face itself, we may observe that, in most instances, it is made of copper, painted and gilt in a more or less ornamental manner. Others are made of slate; and in some cases the face consists of a circular depression, cut in the stonework of the clock-tower, with figures either painted and gilt on the stone, or cut in relief. The making of the wheels and pinions connected with the clock-face, is the work of the same class of persons as those employed in the "movement" wheels, while the decorative parts devolve upon the "clock-face gilder." The dial-plates used for the smaller kind of clocks are very different from these: in some cases they are made of brass, brought to a

fine surface, and silvered, with figures and inscriptions cut in the metal by the "clock engraver," while in other instances the face is made of sheet-copper, coated with enamel, and having figures and letters painted in enamel of a different colour, the work of the "dial-plate enameller," and the "enamel painter."

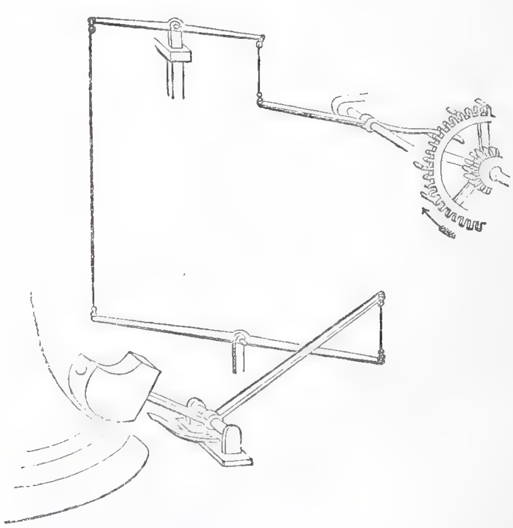
4th. The *regulation*, or pendulum arrangements. We cannot perhaps better illustrate the use of these portions of a clock's mechanism than by endeavouring to answer the following question: Why does not a clock run down in a few hours, when so heavy a weight as sixty or seventy pounds is constantly urging it? Such would be the case if there were no regulating machinery. In a common vertical pocket-watch, we see, under a perforated cover, a bright steel wheel rotating, or rather vibrating, horizontally; in a common clock, we see instead of this a pendulum oscillating to and fro. The mechanism in the first case, is known by the general name of the *escapement*, or *'scapement;* and however different in appearance, the object is the same as that attained by the pendulum of a clock. A spring with a given degree of tension, and a pendulum of a given length, each requires a certain time for the performance of an oscillation; and this important law is made to regulate the movements of the wheel-work in a clock or watch. The steel wheel in a watch is called the "balance wheel," and is governed by a fine spring lying beneath it; but we will here confine ourselves to the pendulum arrangements of a clock. All church clocks have a long wooden pendulum or staff, to the lower end of which a mass of iron is attached. In the Limehouse clock, for example, the pendulum rod is about thirteen or fourteen feet long, and to the lower end of it is attached a mass of cast-iron shaped like a double-convex lens, about thirty inches in diameter, and weighing two hundred pounds. This is suspended from the framework above, and acts in the following manner:—As the wheels revolve, one part of the mechanism gives an impulse to the pendulum, by which it is set in motion: as soon as that impulse has ceased, another urges the pendulum in the opposite direction, and thus the oscillations are produced; but as the pendulum, from the law which governs its movements, has a tendency to make all its oscillations in equal time, it acts as a regulator to the motion of the wheels, and gives it uniformity. As a ball rolling down an inclined plane would move more and more rapidly every second, so would the rotation of the wheels in a clock increase in rapidity every second, were it not that the pendulum absorbs, as it were, all this increase of velocity by increasing its own extent of oscillation, leaving the *time* between every two oscillations unaltered. It is this equality of time in the movements of the pendulum which produces and maintains equality in the movements of the wheels.

The mechanism connected with the pendulum is not very extensive. The rod is a plain piece of wood, squared and smoothed for the purpose. The mass of iron, or "bob," is cast to the required shape and size, and has an adjusting arrangement by which it can be attached to the rod at any part of its height. In some church-clocks there is a graduated arc to measure the extent of the vibrations, which varies with the moving-power. At the upper end of the pendulum are small pieces of mechanism, in iron and brass, by which the rod is brought under the influence of the wheelwork, and set into oscillation. The "bob" of a church-clock pendulum, from the necessary length of the rod, is in most cases beneath the room in which the clock itself is contained.

5th. The *striking* machinery. Our clock has hitherto been a silent monitor. We have offered a few items of explanation as to the manner in which it shows to the eye the progress of time; but there is an appeal to the ear which is equally worthy of notice.

It will easily be conceived that if a bell be hung in a particular spot, and a lever with a hammer at the end be placed near the bell, the lever may without difficulty be so influenced by the wheels of the clock as to cause the hammer to strike the bell. But to cause exactly an interval of an hour to elapse between two such strikings, and to make the number of blows on each occasion correspond with the hour of the day, require mechanism almost as complicated as that by which the indications of the hands are produced. Still greater is this complication when the clocks chime the quarters; and when a regular melody is performed on the bells the arrangements are proportionally more intricate.

In the first place, it must be clearly borne in mind that there is a separate moving-power for the striking machinery, similar in principle to that which impels the going-train. In an eight-day dial, for example, there is one spring-barrel and fusee for the going-train, and another, nearly the same in form and size, for the striking-train. In a church-clock, and in common Dutch clocks, there is one iron weight for the going-train and another for the striking-train, each weight having a cord and barrel appropriated to itself. If we notice the movements of a common domestic pendulum-clock, we shall see that while one of the two weights is continually descending at a slow rate the other descends only while the clock is striking; it is the descent of the last-named weight which causes the striking of the clock, and this striking would be continuous if there were not checks to the descent of the weight. For a large church-clock, where the tones of the bell could not be clearly elicited except by blows from a heavy hammer, the moving power of the striking machinery greatly exceeds that of the going-train. In the Limehouse clock the going-weight is about sixty pounds, whereas the striking-weight is a mass of iron weighing five hundred pounds, and the hammer-head fifty-six pounds. This heavy mass is attached to a rope which winds round a solid wooden barrel, of nearly the same diameter as the barrel before spoken of, and this barrel gives motion to a train of wheels by the customary tooth-and-pinion work. The motion, however, is checked by a catch or detent, except at the termination of each hour, when a curious piece of mechanism connected with the going-train releases the striking machinery, allows the weight to descend, and causes the hammer to strike the bell. Whether the bell be above, below, or at the side of the clock,



the connection between the striking-wheels and the hammer is easily made by levers and pulleys; at the Limehouse clock the bell is beneath the other parts of the mechanism. The mechanism in immediate connection with the hammer and bell of the Limehouse clock is shown in the annexed cut.

But although the release of the striking machinery causes the descent of the weight and the percussion of the bell, yet this does not determine whether the strokes shall be one or many. This is determined principally by two pieces of mechanism called a 'snail' and a 'rack,' the intricate action of which it would be in vain to attempt to explain here. Suffice it to say, that the time during which the striking-weight is allowed to descend varies at different hours of the day; it being sometimes only long enough to permit one blow to be given by the hammer on the bell, and at another time long enough for twelve such blows.

THEORY AND PRACTICE OF NAVIGATION.

CHAPTER V.

III.—AMPLITUDE.

The true amplitude of any object in the heavens is an arch of the horizon contained between the centre of the object when rising or setting, from the east or west points of the horizon; or it is the number of degrees that the centre of the object is distant from the true east or west points of the horizon towards the north or south.

The magnetic amplitude is the arch contained between the centre of the object when in the horizon, and the magnetic meridian; or it is the bearing of the object by compass when in the horizon.

To find the True Amplitude.

To the log. secant of the latitude of the place, without the index, add the log. sine of the sun's declination, reduced to the time of Greenwich; their sum will give the log. sine of the sun's true amplitude, to be reckoned from the east when the sun is rising, and from the west when it is setting; and towards the north or south, according as the declination is north or south.

Then if the true and magnetic amplitudes be both north or both south, their difference is the variation; but if one be north, and the other south, their sum is the variation; and to know whether it be easterly or westerly—suppose the observer looking towards that point of the compass representing the true amplitude, then if the true amplitude be to the right of the observed amplitude, the variation is easterly; but if to the left hand, the variation is westerly.

Example 1.—In latitude 30° 20′ N. on 2d August, 1854; what is the sun's true amplitude, the declination being 17° 37′ N.?

Declination, - -	17° 37′	...	Sine, - - -	9·48094
Latitude, - - -	30 20	...	Secant, - -	0·06394
True amplitude,	E. 20 31 S.	...	Sine, - - -	9·54488

The sun will rise E. 20° 31′ N., and set W. 20° 31′ N.

Example 2.—In latitude 50° 38′ N. on Nov. 2, 1853; what is the sun's true amplitude, the declination being 20° S.?

Latitude, - - -	50° 38′	...	Secant, - -	0·19772
Declination, - -	20 0 S.	...	Sine, - - -	9·53405
True amplitude,	E. 32 38 S.	...	Sine, - - -	9·73177

The sun will rise S.E. by E., nearly.

Example 3.—In latitude 12° 40′ S. on July 10, 1854. the sun rose east 14° 58′ N., as observed by compass. What is the variation?

Latitude, - - - -	12° 40′ S.	...	Secant, -	0·01070
Declination, - - -	22 16 N.	...	Sine, -	9·57855
True amplitude, -	E. 22 51 N.	...	Sine, - -	9·58925
Observed amplitude,	E. 14 58 N.			
Variation, - - - -	7° 53′ W.			

The true amplitude being to the left of the observed amplitude.

Example 4.—In latitude 45° N. on April 27, 1853, the sun was observed by compass to rise E. 42° 25′ N. What is the variation?

Latitude, - - - -	45° N.	...	Secant, -	0·15051
Declination, - - -	13° 54′ N.	...	Sine, -	9·38062
True amplitude, -	E. 19 52 N.	...	Sine, -	9·53113
Observed amplitude,	E. 42 25 N.			
Variation, - - - -	22° 33′ E.			

The true amplitude being to the right of the observed amplitude.

Example 5.—July 3, 1850, latitude 20° 25′ N., and longitude 63° W., the sun set W. 18° 40′ N., about 6h. 12m. p.m. What is the variation of the compass?

	H. M.
Time at ship, - - - - - - -	6 12
Longitude, 63° W. in time, - - - -	4 12
Greenwich time, - - - - - - -	10 24
Sun's declination, July 3d, - - -	23° 0′ N.
Corrected 10h. 24m. (Table), - - -	2′
Corrected declination, - - - -	= 22° 58′ N.

Latitude, - - - -	20° 25′	...	Secant, -	0·02818
Declination, - - - -	22 58 N.	...	Sine, -	9·59128
True amplitude, -	W. 24 36 N.	...	Sine, -	9·61946
Magnetic amplitude,	W. 18 40 N.			
Variation, - - - -	5° 56′			

The true amplitude being to the right.

IV.—AZIMUTH.

The sun's true *Azimuth* is the arch of the horizon intercepted between the meridian and the vertical circle passing through the apparent centre of the sun at the time of observation.

The sun's *Magnetic Azimuth* is the arch of the horizon intercepted between the magnetic meridian and the vertical, apparently passing through the sun.

To find the Variation of the Compass by an Azimuth.

Convert the given time and longitude to the corresponding time at Greenwich. Compute, also, the true altitude of the sun's centre.

When the latitude and declination are of the same name, subtract the declination from 90°; when they are of contrary names, add the declination to 90°, and the sum, or remainder, will be the sun's polar distance.

To the polar distance of the sun add the latitude, and the true altitude of the sun. Find the difference between half this sum and the polar distance.

Then add together—

The log. secant of the altitude, without the indices,
" " latitude, "
The log. cosine of the half sum, and
" " difference, or remainder.

Half the sum of these will be the log. sine of half the sun's true azimuth, to be reckoned from the south in north latitude, and from the north in south latitude; towards the east in the morning, and towards the west in the afternoon. To ascertain whether the variation is easterly or westerly, observe the same rule as in the amplitude.

Example 1.—August 30, 1854, in latitude 25° 36′ N., the sun's altitude a.m. was 14° 25′, and his bearing by compass was found to be 98° S., 18′ E. What is the variation?

	90° 0′			
Declination, August 30th,	9 3 N.			
Polar distance, - - -	80 57			
Altitude of sun, - - -	14 25	...	Secant, -	0·01390
Latitude, - - - - -	25 36	...	Secant, -	0·04487
Sum, - - - - - -	120 58			
Half sum, - - - - -	60 29	...	Cosine, -	9·69256
Remainder, or difference,	20 28	...	Cosine, -	9·97168
				2)19·72301
	46° 38′	...	...	= 9 86150
	2			
True azimuth, - -	S. 93 16 E.			
Magnetic azimuth, -	S. 98 18 E.			
Variation, - - - -	5° 2′ E.			

The true azimuth being to the right.

Example 2.—October 25, 1853, in latitude 30° 26′ N., the sun's altitude p.m. 12° 28′, and his bearing by compass was found to be 78° S., 53′ W. What is the variation?

	90° 0′			
Declination, August 25th,	12 11 S.			
Polar distance, - - -	102 11			
Altitude, - - - - - -	12 28	...	Secant,	0·01036
Latitude, - - - - - -	30 26	...	Secant,	0·06438
Sum, - - - - - - -	145 5			
Half sum, - - - -	72 32	...	Cosine,	9·47734
Difference, - - - -	29 39	...	Cosine,	9·93905
				2)19·49113
	33° 49′	...	Sine =	9·74551
	2			
True azimuth, - - -	S. 67 38′ W.			
Magnetic azimuth, -	S. 78 53 W.			
Variation, - - - -	11° 15′ W., or one point.			

The true azimuth being to the left.

Example 3.—January 31, 1854, in latitude 40° 15′ S., the folowing altitudes and azimuths were taken a.m.:—

Altitudes.	Azimuths.
12° 18′	S. 97° 20′ E.
12 46	97 0
13 20	96 30
14 15	96 20
14 50	95 15
5 67 29	5)482 25
Mean, 13° 29′	Mean, S. 96° 29′ E.

What is the variation?

	90° 0′			
Declination, Jan. 31st,	17 23 S.			
Polar distance, - -	72 37			
Altitude, - - - -	13 29	...	Secant, -	0·01214
Latitude, - - - -	40 15	...	Secant, -	0·11734
Sum, - - - - -	126 21			
Half sum, - - -	63 10	...	Cosine, -	9·65456
Difference, - - -	9 27	...	Cosine, -	9·99407
				2)19·77811
	50° 46	..	Sine, - =	9·88905
	2			
True azimuth, -	S. 101 32 E.			
Magnetic azimuth,	S. 96 29 E.			
Variation, - - -	5° 3′ W.			

The true azimuth being to the left.

Example 4.—May 10, 1854, at Glasgow, latitude 55° 51′ N., and longitude 4° 16′ W., the sun's altitude p.m., about 6h., was found to be 20° 30′, and the bearing by compass 86° S., 28′ W. What is the variation of the compass?

	H. M.
Apparent time at Glasgow, May 10th, - - -	6 0
Longitude, 4° 16′ in time (Table), - - -	0 17 W.
Apparent time at Greenwich, - - - -	6 17
Sun's declination at Glasgow, - - -	17° 37′
Corrected for 6h. 17m., - - - -	+ 4
Sun's declination at Greenwich time, - -	17 41 N.
	90 0
Sun's polar distance, - - - - - -	78° 19′

Sun's altitude, - -	20° 30′	...	Secant, -	0·02841
Latitude, - - - -	55 51	...	Secant, -	0·25076
Polar distance, - -	78 19			
Sum, - - - - -	154 40			
Half sum, - - - -	77 20	...	Cosine, -	9·34100
Difference, - - -	0 59	..	Cosine, -	9·99994
				2)19·62011
	40° 13′	...	Sine, - =	9·81005
	2			
True azimuth, -	S. 80 26 W.			
Magnetic azimuth,	S. 86 28 W.			
Variation, - - -	6° 2′ W.			

The true azimuth being to the left-hand side.

Example 5.—November 12, 1853, at Liverpool, 53° 24′ N., and longitude 2° 58′ W., the altitude of the sun was observed to be 12° 28′, about 6h. 30m. p.m., and the bearing by compass found to be 36° S., 40′ W. What is the variation of the compass?

	H. M.
Apparent time at Liverpool, Nov. 12th, - -	6 30
Longitude, 2° 58′ in time (Table), - - -	0 11 W.
Apparent time at Greenwich, - - - -	6 41
Sun's declination at Liverpool, Nov. 12th, -	17° 46′ S.
Corrected for 6h. 41m. (Table), - -	+ 4
Sun's declination at Greenwich time, - -	17 50
	90
Polar distance, - - - - - - -	107° 50′

Sun's altitude, - -	12 28	...	Secant, -	0·01036
Latitude, - - - -	53 24	...	Secant, -	0·22459
Polar distance, - -	107 50			
Sum, - - - - -	173 42			
Half sum, - - - -	86 51	...	Cosine, -	8·73997
Difference, - - -	20 59	...	Cosine, -	9·97020
				2)18·94512
	17° 16′	...	Sine, =	9·47256
	2			
True azimuth, - -	S. 34 32 W.			
Magnetic azimuth,	S. 36 40 W.			
Variation, - - - -	2° 8′ W.			

The true azimuth being to the left.

Example 6.—October 31, 1854, in latitude 28° 36′ N., longitude 38° 20′ E., the altitude of sun's lower limb was observed to be 13° 40′ about 6h. p.m., and the bearing by compass to be 00° S., 00′ W., the observer's eye being 20 feet above the sea. What is the variation of the compass?

	H. M.
Apparent time at ship, Oct. 31st, - - -	6 0
Longitude, 38° 20′ in time (Table), - -	2 33 E.
Apparent time at Greenwich, - - - -	3 27
Sun's declination at ship, Oct. 31st, - -	14° 6′ S.
Corrected for 3h. 27m. (Table), - -	+ 2
Sun's declination at Greenwich, - - -	14 8 S.
	90
Polar distance, - - - - - - -	104° 8′

Observed altitude of sun's lower limb,	- -	13° 40′
Corrected from table, + 7′,	- - - - -	7
True altitude of sun's centre,	- - - -	13 47
Latitude,	- - - - - - - -	28 36
Polar distance,	- - - - - - -	104 8
Sum,	- - - - - - - - -	146 31
Half sum,	- - - - - - - -	73 15
Difference,	- - - - - - - -	30° 53′
True altitude of sun's centre, secant,	- -	0·01269
Latitude, secant,	- - - - -	0·05651
Half sum, cosine,	- - - -	9·45969
Difference, cosine,	- - - -	9·93360
		2)19·46249
32° 35′ ... Sine,	- =	9·73124
2		

True azimuth, - S. 65 10 W.
Magnetic azimuth, S. 70 20 W.

Variation, - - - 5° 10′ W.
The true azimuth being to the left.

Example 7.—On June 1, 1853, in latitude 55° 57′ N., the sun's declination being 22° 7′ N.; what is the azimuth and altitude at 6 o'clock?

To find the Altitude.

Radius : sine latitude : : sine declination : sine altitude.

Radius, - - - - - - - -	10·00000
Is to sine latitude, 55° 57′, - - - -	9·91840
As sine declination, 22° 7′, - - - -	9·57576
	19·49416
	10·00000
To sine altitude, 18° 11′, - - -	= 9·49416

To find the Azimuth.

Radius: cosine latitude : : tangent declination : tangent azimuth.

Radius, - - - - - - - -	10·00000
Is to cosine latitude, 55° 57′, - - -	9·74812
As tangent declination, 22° 7′, - - -	9·60895
	19·35707
	10·00000
To tangent azimuth, 13° 9′, - -	= 9·35707

At 6 a.m. the sun is E. 13° 9′ N., and at 6 p.m. he will be W. 13° 9′ N.

Solution by the Mathematical Rule.

Example 8.—In latitude 36° 20′, the sun's azimuth at the hour of 6 being 10° 15′; what is the declination and altitude?

To find the Declination.

Cosine latitude : radius : : tangent azimuth : tangent declination.

Cosine latitude, 36° 20′, - - - -	9·90611
Is to radius, - - - - - - -	10·00000
So is tangent azimuth, 10° 15′, - - -	9·25727
	19·25727
	9·90611
To tangent declination, 12° 39′, - -	= 10·35116

To find the Altitude.

Radius : sine azimuth : : tangent latitude : tangent altitude.

As radius, - - - - - - -	10·00000
Is to sine azimuth, 10° 15′, - - - -	9·25028
So is tangent latitude, 36° 20′, - - -	9·86656
	19·11684
	10·00000
To tangent altitude, 7° 27′, - - -	= 9·11684

Solution by the Mathematical Rule.

Example 9.—In latitude 35° 20′ S., the sun's altitude at 6 p.m. being 9° 50′; what is the declination and azimuth?

To find the Declination.

Sine latitude : radius : : sine altitude : sine declination.

As sine latitude, 35° 20′, - - - - -	9·76218
Is to radius, - - - - - - -	10·00000
So is sine altitude, 9° 50′, - - - - -	9·23244
	19·23244
	9·76218
To sine declination, 17° 10′ S., - -	= 9·47026

To find the Azimuth.

Radius : cotangent latitude : : tangent altitude : sine azimuth.

As radius, - - - - - - -	10·00000
Is to cotangent latitude, 35° 20′, - - -	10·14941
So is tangent altitude, 9° 50′, - - -	9·23887
	19·38828
	10·00000
To sine azimuth, W. 14° 9′ S., - -	= 9·38828

Solution by the Mathematical Rule.

Example 10.—Set the rod, C, to 55° 57′ on the quadrant, A; then move the slide, F, till it cuts 22° 7′ on the line of sines on the rod, C; and 18° 11′ will be given on F, the altitude, and 13° 9′ will be given on B, the azimuth.

Example 11.—Set the rod, C, to the latitude 36° 20′ on the quadrant, A; then move the slide, F, till it cuts 10° 15′ on the line of sines on the rod, B; and the rod, C, will cut 7° 27′ on the line of sines on F, being the altitude; and the slide, E, will cut 12° 39′ on the line of sines on the rod, C, being the declination.

Example 12.—Set the rod, C, to 35° 20′ on the quadrant, A; then move the rod, F, till the rod, C, cuts 9° 50′ on the line of sines; and 14° 9′ will be given on the line of sines on the rod, B, being the azimuth; and 17° 10′ will be given on the line of sines on the rod, C, being the sun's declination.

BLEACHING.

CHAPTER III.

COTTON BLEACHING CONTINUED—WOOL AND SILK BLEACHING.

Having in the last chapter explained the details of the different stages of the bleaching process, we must proceed to describe some of the principal processes followed in calico-printing establishments, with the view of calling attention to those which present the greatest advantages, and pointing out the improvements of which they are susceptible.

FIRST STAGE—SCOURING.

The pieces of calico receive:

1. A lime lixiviation of twelve hours, followed by a thorough cleansing.

2. Lixiviation with caustic soda, in the proportion of fifty gallons of lie at 1° AB to 1000 yards of calico, exposing it to a continuous jet for a period of ten hours at least, and a thorough cleaning by the fuller.

3. A second lie, like the preceding, followed by a third rinsing.

4. A third lie, always of caustic soda at 1° AB, and a fourth rinsing.

The quantity of cloth which is commonly submitted to these lixiviations depends on the capacity of the apparatus, some of which admit of the lixiviation of so much as 30,000 yards of calico at a time, while others do not admit of more than 4,000.

SECOND STAGE—DECOLORATION.

5. An immersion of 30 minutes in a bath consisting (for the same quantity of 1000 yards) of 200 gallons of water, holding in solution 2 gallons of chloride of lime at 8° AB, but to which should be added, after withdrawing 500 yards of the goods, from $\frac{1}{5}$th to $\frac{1}{3}$d of a gallon of chloride of lime.

6. Immersion of 30 to 40 minutes in 200 gallons (always for the same quantity of stuff) of a water soured with 8 to 9 lbs. of concentrated sulphuric acid.

7. Washing and rinsing.

8. Lixiviation, like No. 2 above.

9. Washing and rinsing.

10. Immersions in chloride, like No. 5.

11. Acid bath, like No. 6.

12. New Lixiviation with caustic soda, like No. 2.

13. Immersion of twelve hours in a bath of sulphuric acid, marking 1° 5 AB.

14. Washing and rinsing.

This process gives a very good white, but is not scientific; for the lime first employed forms an insoluble soap, of which only a part is removed by the mechanical operations of rinsing, whilst the rest, remaining in intimate union with the fabric, resists the action of the chloride to such an extent, that it is only after undergoing the immersions Nos. 5 and 6, and finally the lixiviation No. 8, that the chlorine exerts its action on the parts protected by this calcareous soap.

We might give here a multitude of processes still practised in some calico-printing works, without being based on any principle, but we prefer to give a statement of two others totally different from the preceding: the first is due to M. Gréan, of Troyes;* the second, more generally employed, is based on principles which we have already developed, and is designated by some bleachers *American bleaching.*

THE GREAN PROCESS.

FIRST STAGE—SCOURING.

The goods are—

1st. Immersed in a soda liquor of two alkalimetric degrees, containing six-tenths of a part of pure soda to three hundred parts of water, or one part of soda at 60° to three hundred parts of water, during forty-eight or fifty hours.

2d. Fulled and washed.

3d. Submitted for twenty-four hours to the action of a first lie of caustic soda, at twelve alkalimetric degrees.

4th. Fulled and washed.

5th. Immersed for half-an-hour in a hydrochloric acid bath, formed of one part of acid to twenty of water.

6th. Fulled and washed.

7th. Submitted for twenty-four hours to the action of a lie of caustic soda, at nine alkalimetric degrees.

8th. Fulled and washed.

9th. Immersed in the hydrochloric acid bath, as in operation No. 5.

10th. Submitted for twelve hours to the action of a lie of caustic soda at 6°.

* Memoir on the destruction of the fabrics in bleaching and dyeing, by M. Grean, sen., Troyes, 1835.

SECOND STAGE—DECOLORATION.

11th. Immersed twice successively, for three hours each time—namely, 1st, In a bath of bleaching powder at 1·5° of the chlorometer; 2d, In a bath of the same material at 1° of the chlorometer.

12th. Submitted for four hours to the action of a warm bath of caustic soda at 4° of the alkalimeter, maintained for two hours in ebullition.

13th. Immersed in a hydrochloric acid bath, similar to those of operations 5 and 9.

14th. Fulled and washed.

15th. Immersed for three hours in an oxychloride of calcium bath at three-fourths of a chlorometric degree.

16th. Worked in a hydrochloric acid bath, composed of one part of the commercial acid to three hundred parts of water.

17th. Lastly, perfectly fulled and washed.

M. Grean was the first to lay down, as a principle, that the immersion of the fabrics in the bleaching solution should only take place when they are deprived of all the fatty matters. It will also be observed that, in his process, the scouring operations, all done on scientific principles, tend to gradually saponify the fatty substances, and to set at liberty, by the immersions in hydrochloric acid, the fatty acids which they contain, and which, by combining with the resinous bodies, promote the solution of the latter in the alkaline lies, which always follow the acid immersions. Lastly, the process under consideration has this further peculiarity, that the goods, on being taken from the bleaching solution, instead of being treated with an acid that sets the chlorine at liberty, are boiled in a soda lie, which has the effect of producing a double decomposition, and, finally, of bringing the fabric in contact, at an elevated temperature, with an oxychloride of sodium, which contains, in excess of base, all the lime displaced by the lie.

AMERICAN PROCESS.

FIRST STAGE—SCOURING.

The unbleached pieces receive:—

1st. A lixiviation with lime for from twenty to twenty-four hours; thirty-six pounds of lime to one thousand pieces of unbleached cloth, three quarters of a yard wide, and instead of water, the residue of lie No. 3.

2d. A washing and rinsing.

3d. A second lime lixiviation, of the same duration and composition as the first.

4th. A washing and rinsing.

5th. An immersion in tepid sulphuric acid at 1°.

6th. A washing and rinsing.

7th. A lixiviation with carbonate of soda—formed of the residue of lie No. 12, adding about two pounds of carbonate of soda for each thousand yards of cloth, three-quarters of a yard wide.

8th. A washing and rinsing.

SECOND STAGE—DECOLORATION.

9th. An immersion of some hours in a solution of bleaching powder, so diluted that it does not give an indication by the areometer, and when saturated with an acid does not sensibly disengage chlorine.

10th. An immersion in hydrochloric acid at 2° AB.

11th. A washing and rinsing.

12th. A second lixiviation in carbonate of soda for twenty-four hours. To the quantity of water required for the lixiviation of a thousand yards of calico, are added about nine pounds of the carbonate.

13th. A washing and rinsing.

14th. A second immersion in hypochlorite of lime, similar to operation No. 9.

15th. A second immersion in acid at 2° AB, similar to operation No. 10.

16th. A thorough washing and rinsing.

Of the three processes which we have detailed, this is the only one in which carbonate of soda is used instead of caustic soda: the employment of this salt in bleaching has brought back this operation to the system practised in families of

bleaching with ashes, which, as is known, contain only carbonate of potassa. The alkaline carbonates, contrary to the ideas at first entertained of them, dissolve saponified fatty bodies quite as well, if not indeed more readily, than their bases in the caustic state, and have the advantage over the latter, of making the calcareous soaps which might have escaped the decomposing action of the latter undergo a double decomposition, which transforms them into soaps with a soluble soda or potassa base, and into an insoluble lime carbonate.

This process, whether regarded in an economical view, or with reference to the principle itself, on which it is based, is much more advantageous than the preceding, and is that which is now generally practised.

Continuous Bleaching.—The fall in price which calicoes have undergone has had the natural effect of compelling the manufacturer to introduce all the economy possible into his bleaching processes. In several establishments, in order to reduce the expense of manual labour, several hundreds of pieces are sewed together, one to the end of the other; and interposing a number of traction rollers, or rollers which serve simply to support the goods, they are made to pass by an uninterrupted movement from the lixiviating vat to beneath the cleansing apparatus—the beater, for example; from this machine, into the bath of acid or chloride, according to the progress of the operations, and so on in succession: this is what is termed *continuous bleaching*, which realizes the perfection of mechanical treatment or manipulation, as the *American* process realizes that of the chemical operations.

All that we have hitherto said of the chemical operations of bleaching applies to the bleaching of cotton goods. Hempen and linen fabrics are treated also in the same manner; but the scouring operations must be much more numerous; they require at least, according to the quality and fineness of the goods, four lime lies, each followed by an acid bath and a carbonate of soda lixiviation, before entering on the operations of the second stage of bleaching, that of the decolouration.

When the fabrics are very fine, a certain quantity of soft soap is added to the lie to increase its power. Provided the fibres of the fabrics have been well cleared of the waxy substance which covers them, and the colouring matter well exposed, the bleaching proceeds rapidly; in the contrary case, threads perfectly bleached are found accompanied by threads retaining a degree of colour, of which it is impossible to deprive them without injuring more or less the parts already bleached.

From all that we have just stated, it will be seen that, to insure the success of bleaching operations in general, it is requisite:—

1st. Directly to attack the goods with lime, in order to saponify the fatty bodies, to prevent the formation of an organic mordant, and to modify at the same time the colouring matter inherent in the fabric, but never forgetting that the goods cannot, without danger, be in contact with air and with the lime at the same time.

2d. To clean the goods well after each treatment with lime, to assist the more, by this mechanical operation, the chemical treatment which follows.

3d. To decompose the calcareous soap by an acid (the hydrochloric is always preferable to the sulphuric acid), to find the degree of temperature and proportion of acid fitted to accomplish this decomposition without injury to the fabric, and not to lose sight of the fact, that the bath has likewise the effect of dissolving the resinous substance, and a portion of the colouring matter, so that being once saturated with the latter, being no longer sufficient, whatever its degree of acidity otherwise, to decompose the calcareous soap, it must be removed.

4th. To lixiviate with carbonate of soda in preference to caustic soda, which wears out the fibre, and always produces a less perfect white.

5th. To immerse the goods in a very clear solution of chloride of lime, in order to avoid the perforations which take place at those points of the fabric where the insoluble compound lodges, and further to dilute this solution with a large quantity of water, either prolonging the immersion, or repeating it, or raising the temperature of the bath.

6th. To employ hydrochloric acid in all the acid baths which succeed the immersions, inasmuch as the decolourizing effect which results from it becomes proportional to the chloruretted oxidized compound, which exists on the stuff, and which is thus utilized—not only the hypochlorite, but likewise the chlorite and the chlorate.

7th. To give great attention to the effect of the souring on the goods, to make them undergo, if the oxides be not completely removed, a new treatment with acid. If this supplementary operation be still insufficient, which sometimes happens when the fabric retains oxidized iron in that isomeric state in which it is insoluble in acids, the goods should be impregnated, without hesitation, in a water slightly acidulated with a mixture of oxalic and tartaric acids, to be afterwards steamed. The ferric oxide being then reduced, all the iron disappears, and, by a new passage of the goods in a bath of dilute acid, the white becomes perfect.

Even when the goods have been made to undergo all the operations we have just described, and when they have attained all the whiteness desirable, a prudent bleacher should always submit a piece taken at random, to tests which may assure him of the success of certain kinds of printing that require a perfect white. Indeed, the fatty bodies which may remain on these goods, would inevitably produce spots upon them: if passed, for example, into an indigo vat, the colour would not take equally well on all parts; if printed with uniform grounds, the fatty parts, by fixing more of the colouring matter, would present inequalities of shades, which always diminish the value of a stuff; lastly, in printing on *white grounds*, some of the parts which ought to remain white, attracting to themselves the colouring matter of the dye-vat, the operator would find himself reduced to the unhappy alternative of either retaining the white ground with its spots (not to compromise the colours too much), or if more or less injuring the latter to restore to the spotted parts their primitive purity.

To make sure whether a portion of goods intended for printing is freed of all matter foreign to the fibre, a piece of it is put along with mordanted goods, and the whole are plunged into a madder bath, in which it will be less coloured in proportion as the bleaching has been more perfect.

After bleaching, the goods are dried by different processes, which we shall describe in connection with the bleaching of woollen and silk fabrics.

BLEACHING OF WOOLLEN AND SILK STUFFS.

The operations to which woollen and silk stuffs are submitted for the purpose of bleaching them, differ only by slight modifications which we shall take care to point out. As in the bleaching of vegetable fabrics, these operations are divided into two classes—the first intended to free the textile fibres of the fatty, waxy, and resinous substances with which they are impregnated; the second, to modify the colouring matter inherent in these fibres, in such a manner as to bleach them as completely as possible. We shall still, therefore, in this case, have to examine the operations of scouring, properly so called, and then the operations of bleaching, or the decolouration of the textile fibre.

FIRST STAGE.

Scouring.—The grease, and the waxy and resinous substance with which wool and silk are accompanied, naturally and artificially (in this latter case, in consequence of the operations they have passed through to bring them from the rough state to that of the prepared fabric), cannot be removed from them by the same conditions as from hempen and linen fabrics. Thus, for example, the saponification of these fatty bodies by caustic alkalies must be renounced, since these alkalies either dissolve at the same time the fibre of the animal fabrics—an effect produced by potash and soda—or render it unfitted to attract the colouring matters, as when lime is used. To destroy them, the carbonate of soda (soda in crystals) is always employed; but as this alkaline compound is insufficient to saponify or dissolve the whole of them, it is requisite to interpose the action of soap, which partly promotes the saponification of the fatty bodies, and partly acts in virtue of its valuable property, of being decomposed under the influence of water, and,

by its fatty acids, of rendering mixible with water substances which are not so of themselves. There cannot be a doubt that in the bleaching of woollens the soap performs at one and the same time these two parts, and that in this way the disappearance of the fatty substance detected in this fibre by M. Chevreul is due to it. The conditions in which these alkaline and soapy substances should be made to act, are likewise not the same as those by which the scouring of the vegetable fibre is accomplished; for instead of performing the lixiviations at the elevated temperature at which the fatty body saponifies best, one is obliged, for the safety of the fabric which the action of the alkali deteriorates, and which contracts and felts together the more it is exposed to a higher temperature, to perform these lixiviations at a temperature ranging from 60° to 65° Cent. (140° to 150° Fahr.) The apparatus, by means of which woollen fabrics are mechanically scoured, are not less different from those employed for the bleaching of calico. Woollen stuffs require to be stretched in passing through a warm alkaline solution; otherwise, they contract unequally, and the contractions drawn in different directions injure the quality and beauty of the fabric. To avoid this, a peculiar machine is used to impregnate the goods with the alkaline solution, or with the alkaline soap. Each piece passes once or oftener to the bottom of a trough filled with lie, and, on emerging, is pressed between two rollers, which cause the excess of lie to fall back into the trough, while the stuff is rolled up on moveable wooden cylinders.

It is evident that the goods must be passed several times through the carbonate of soda alone; then through the same carbonate mixed with soap, to take away all the fatty bodies existing on the wool: it is only, therefore, after having given the latter a sufficient number of lies, followed by washings with warm water, that the operator passes to the operations which constitute the second phasis of the bleaching process.

SECOND STAGE.

Decolouration.—When the silks or woollens are freed, as much as possible, from the fatty, resinous, or waxy bodies which accompany them, they are exposed to the action of the sulphurous acid which bleaches them; but this agent, instead of acting like chlorine and transforming the colouring matters into other products more or less coloured, which the fabric no longer retains, merely unites with the colouring matter peculiar to the fabric, to form with it an intimate colourless combination which remains adherent to the fibre.

The sulphurous acid is employed in the gaseous state, or in solution in water.

Decolouration by Gaseous Sulphuric Acid.—It would be difficult to assign the epoch at which the action of the vapour resulting from the burning of sulphur was first applied to the bleaching of stuffs of wool, silk, and even of straw. This operation, termed *sulphuring*, is so simple that any one can perform it; it is sufficient to put into a chamber, or into a large box, or lastly into a wooden tub hermetically closed, and in which the goods to be bleached in this manner are spread out, a vessel full of sulphur, to which a flame is applied. The sulphurous acid produced by this combustion, coming in contact with the goods which have been previously moistened, reacts upon them and deprives them of colour. The essential point is to make the best arrangements for the proper distribution of the goods, and the most perfect combustion of the sulphur, without loss of sulphurous acid, and without accident to the stuff; lastly, it is important to arrange so as to utilize the sulphurous acid with the least possible loss of it.

The apparatus employed for sulphuring are of two kinds, though all founded on the same principle: in the one kind, the combustion of the sulphur is effected at the expense of the oxygen in the chamber in which the sulphuring is performed; in the other, it is effected by the introduction of a certain quantity of the external air.

In the latter case, the goods are introduced into a chamber about five yards in the sides, and six in height. The door of this chamber closes hermetically, and at the upper corners are openings furnished with valves, by means of which the air can be renewed. At the lower corners are two openings closed with bricks, and by which a vessel filled with inflamed sulphur may be introduced at pleasure. In the interior of this flagged chamber are firmly fixed 16 planks ranged two by two in four stages. On each of these planks, over their whole length, at intervals of two inches, are fixed wooden pegs from 3 to 4 inches centimetres in length, furnished at their ends with a small knob, and which, diverging slightly, permit the pieces to be stretched from one plank to the other without slipping or falling down. The pieces to be sulphured are sewed together; one end is attached to the peg at one of the corners of the plank in the upper stage, the stuff is then passed behind the first peg of rack which corresponds to it, and the teeth of which diverge in an opposite direction to the first. It is then carried back to the second peg of the first rack, from this to the second of the second rack, and so on till the racks formed by the four planks are completely covered. After repeating the same operation in succession on the lower stages, the chamber is hermetically closed, introducing into it by the lower openings the earthen pans containing the inflamed sulphur. These openings are immediately shut, and the sulphur burns at the expense of the oxygen, whilst the sulphurous acid resulting from this combustion dissolves in the water with which the fabric is impregnated, and penetrating into the pores of the fabric, exercises its action on the colouring matter.

This operation is not so economical as it is simple; it inevitably entails great losses of sulphurous acid. The sulphur, in burning, dilutes the air of the chamber, and forces it out by the vents which always exist in greater or less number, in spite of all the precautions taken to stop up the chinks. This air mechanically drags with it a certain quantity of the acid; and that which remains in the chamber after the operation is likewise lost, since it must be expelled in order that the workmen, whose business it is to remove the sulphured goods and commence a new operation, may be able to do so without danger. This is not the only disadvantage: without having at disposal two chambers of this kind, the establishment in which this process is used has always to suffer interruptions of the work more or less prejudicial to its interests. Lastly, the combustion of the sulphur thus lighted at the lower part of the chamber is often stifled, and the sulphurous acid, denser than the air, does not diffuse itself uniformly in all parts of the stuff.

To insure in this respect an operation with good results, it would suffice, in our opinion, to place above and outside the chamber a fire-place, over which should pass a bent earthenware flue, one of the branches of which should descend to the middle of the chamber, whilst the other should open into the upper part. The burning of the sulphur being effected at the point corresponding to the fire, a current would necessarily be established, and the sulphurous acid would diffuse itself on the goods from the higher to the lower stage, whilst the air which would occupy the middle region would constantly arrive at the burning substance, and feed the combustion.

Whatever be the mode of sulphuring with the sulphurous gas, care must be taken to isolate the goods from the fire-place at which the sulphurous acid is formed by means of packing-cloths slightly moistened. Without this precaution, especially if crude sulphur is used, the impurities which it contains, by being deposited in the stuff, would damage it more or less.

Liquid Sulphurous Acid.—D'Oreilly was the first, as far as we know, who proposed to substitute liquid sulphurous acid for the gaseous acid, which had been employed from time immemorial. This author, in his work, treats two questions: he examines the preparation of the liquid sulphurous acid, and he points out what are the preliminary operations which the woollens should be made to undergo before submitting them to the action of this acid; he is thus led to establish the necessity of commencing by removing, through the agency of carbonate of potassa, soap, and tepid water, all the fatty bodies with which the wool is impregnated before bringing it in contact with the sulphurous acid; it is only then that he advises immersing the goods in a vat filled with water saturated with this acid. He states that one immersion of four hours gives a much purer white than the preceding process. From the results obtained by D'Oreilly, one is surprised that this process has not been adopted; we know only one manufacturer who

employed it, and that in a cumbersome manner, since he put the sulphurous acid of the sulphuring chambers over crystals of soda to produce sulphite of soda, which he afterwards decomposed under the influence of a certain quantity of water by the proportion of sulphuric acid necessary to transform it into sulphate of soda and sulphurous gas, both of which remained in solution.

For the preparation of the sulphurous gas, there is not, in our opinion, any process more economical, easier, and more within the reach of every one, than that which consists in calcining a mixture of sulphate of iron and sulphur. As this calcination is effected under a dull red heat, any kind of iron vessel may serve for the purpose, but the most suitable form is that of the cylinder. One might even apply to this preparation the apparatus appropriated to the fabrication of nitric acid in cylinders of cast-iron, whereof several works on chemistry, and especially the treatise of M. Dumas, give a description.

When the stuffs have been sufficiently scoured, and then decolourised by sulphurous acid, they always receive, especially when the fabrics are of twilled cotton, an *azuring* or *blueing*, intended to heighten the white, or rather to mask the yellowish tint which they usually retain. Some years ago this blue colouration was given by means of a preparation which had copper for its base, but this mode of blueing was abandoned as soon as the serious accidents which often result from it were recognised; more than once, indeed, it was proved that stuffs thus treated, and which had been printed with all possible care, presented, after their *steaming*, on the reserved parts of the fabric, stains more or less deep, which M. Chevreul attributes to the presence of copper. At present it is carmine, or the acetate of indigo, alone or mixed with alumina, which is used for azuring.

Having thus explained the agents and apparatus employed for the bleaching of woollens, we proceed to give a detailed view of the process most highly recommended when operating on a large scale.

Supppose that after being singed or ironed, and washed with water, 40 pieces, of 45 yards each, have been wound by fours on 10 rollers; these goods are then subjected to the following treatment:—

1st. Passed twice into an alkaline soap bath, heated to 60° or 65° Cent. (140° to 150° Fahr.) composed of 40 lbs. of crystallized carbonate of soda, and 2 lbs. of soap.

2d. Rinsed in warm water.

3d. Passed twice into a bath, heated to 60° or 65° Cent., formed of 20 lbs. crystals of soda.

4th. Rinsed in warm water.

5th. Passed into the sulphuring apparatus for ten hours, using 20 lbs. of sulphur, or 8 ounces per piece.

6th. Rinsed in warm water.

7th. Passed twice into a bath heated to 60° or 65° Cent., containing 14 lbs. crystallized carbonate of soda.

8th. Passed twice into a bath heated to 60° or 65° Cent., containing 11 lbs. crystallized carbonate of soda.

9th. Rinsed in warm water.

10th. Passed into the sulphuring apparatus, using 15 lbs. of sulphur, or 6 ounces per piece.

11th. Passed into tepid water.

12th. Passed into a blue bath.

When the stuffs to be bleached are intended for the printing of dark-coloured grounds, of flowers or any other detached subjects, one may stop at the 6th operation (the rinsing of the goods with hot water), and put them in the blueing vat. When, on the contrary, these same stuffs are to receive grounds of delicate colours, it is indispensable to make them undergo the above-mentioned series of operations, to avoid stains.

In closing this subject, we deem it proper to recapitulate the principal conditions of success in the bleaching of woollens and mixed-woollen fabrics.

1. The first is to scour the fabric well; and this is effected by treating it first with soap, then with carbonate of soda, and subjecting it to numerous washings with tepid water.

2. The second is to protect the fabric from the direct action of the sulphurous gas during the operation of sulphuring by this gas, the impurities of which might injure the stuff, or at least produce stains upon it.

3. The third is, not to conduct the washings at too high a temperature after the operation of sulphuring, to prevent the destruction in part of the combination which is formed between the sulphurous acid and the colouring matter.

BLEACHING OF SILK STUFFS.

Silk stuffs which are intended to be bleached, have either already been partly bleached by the scouring operations which the silk has been made to undergo before weaving, or they are in the raw state.

In the former case, it is sufficient to immerse the goods for some time in running water; they are then boiled for an hour in a bath consisting of 2 ounces of soap and 16 ounces of bran for each piece of 8 to 10 yards. The bran saturating by its acid the excess of alkali of the soap, the latter weakens the silk less. On being taken from this bath, the goods are rinsed in a water heated to 50° Cent. (or 120° Fahr.), then washed in cold water, and finally submitted to the dash-wheels.

In the second case, the goods, after being introduced into a bag, are immersed in a boiler filled with a water which holds in solution 4 ounces of soap per pound of dry silk. After having heated and kept the whole in ebullition for two to three hours, the stuff is withdrawn from this bath to rinse it in running water. When well scoured, it receives a second soap bath similar to the preceding, and is again scoured by the dash-wheel. The scouring finished, it is passed, for ten to fifteen minutes, into a water containing for each piece half-an-ounce of crystallized carbonate of soda. On proceeding from this alkaline bath, it is again scoured, then carefully rinsed, and next passed into a water sharpened with sulphuric acid, but which should scarcely be indicated by the areometer; in fine, the operation is concluded by giving a last washing with warm water, beating and rinsing in running water.

Silk fabrics thus bleached are pure enough for every kind of printing in which dark colours are used, such as those of madder, Prussian blue, cochineal amarynth and violet, and fine brown colours in general; but when it is desired to print lighter colours, the goods should receive a slight sulphuring. It is for fabrics intended for this purpose that liquid sulphurous acid is more especially advantageous, since it may be employed in a very weak proportion. It is not unnecessary to remark here, that this acid should only be applied with the greatest circumspection to the bleaching of silk—that it always communicates a more or less yellow tinge, and even ends by injuring the fabric when the bleaching has been performed with it.

BOTANY.

CHAPTER XVI.

EXCRETIONS—MISCELLANEOUS PHENOMENA.

The doctrine of *excretion*, or the expulsion of exhausted matters out of the system of plants, has been alternately admitted and denied by writers. It has been supposed to take place both from the leaves and roots.

The evidence usually adduced to support excretion from leaves, amounts only to a proof of the ordinary process of exhalation. It is superfluous, therefore, to pursue such illustrations further than in the limited sense which their construction may allow of change or redundancy passing upon that which has been eliminated; for it is upon the question, whether these matters have already expended their nutritive uses, or have acquired properties actually noxious to the plant, that a true excretion depends.

With regard to the gases which are exhaled both through the day and during night, a simple transmission from the soil is not sufficient to make them pass into the character of excretions; but they cannot fail to be so when they arise from compositions within the body of the plants, out of which they are afterwards discharged. How far the liquid matter, which is so plentifully

exhaled, is to partake of an excretory character, must depend in like manner on the results of its formation. In many cases that which is parted with in the leaves had been the vehicle of other materials held in solution by it, and which became consolidated on the sides of the cells or vessels when separated by the escape of the fluid. Silica has been conjectured to be thus precipitated, and after its deposit seems incapable of being again transferred or ejected. But whether the water that passes off is in no degree unaltered, remains for discovery.

As to the root, Brugmans, according to Humboldt (*Journ. de Physique Delametherie, t. iv., p.* 388), is said, on placing lolium or ryegrass in a glass of water, to have observed daily at the extremities of the roots a small bead of viscous matter, which, when detached, was as often renewed on the next day. But Darwin suggests with apparent reason, that this effect may have been produced by the gradual decomposition of the extremities of the roots in their unnatural situation.

A number of experiments on the same subject by M. Macaire, was first published in the fifth volume of "Mémoires de la Société de Physique et d'Histoire Naturelle de Genève," and repeated in the "Annales des Sciences Nat." xxviii. 402. A specimen of Chondrilla muralis, being carefully cleansed of its earth, was immersed in filtered rain-water, which was changed every two days; and the plant continuing to flourish, at the end of eight days, the water, then tinged with yellow, indicated both by smell, taste, and chemical tests, the presence of a bitter narcotic substance of a reddish-brown colour, when left by evaporation. This residuum was not obtained when the roots and stems were separately detached; and M. Macaire concluded, that it was the result of an exudation from the roots in entire plants in a healthy state. But this experiment is open to the grave doubt expressed in the former case, more especially since a narcotic gum is naturally secreted by the genus Chondrilla. And the same objection may be urged against the conclusiveness of his experiments on Annual mercury, Common groundsel, and Common cabbage, each of which, after being immersed in diluted solutions of acetate of lead, lime, and salt, gave out perceptible quantities of these matters when afterwards placed in separate vessels of pure water. De Candolle, who has strongly urged the excretory action of the root, remarks, that certain maritime plants which yield soda, flourish in remote situations under the distant sea breezes, and impregnate the soil in their immediate vicinity with the salt which they had imbibed by their leaves. But in this case also it requires consideration, whether the saline impregnations, of which he considers the leaves to be sensible, had not previously affected the soil.

Upon the whole, though they do not appear clearly from these experiments, it is not improbable that certain excretions, consisting of organic and inorganic matters, are given off by plants, by a process of exosmose; and though that emitted by each species was thought by Macaire and De Candolle to deteriorate that species, Daubeny and Gyde have experimentally proved that they are not injurious.

IV. Of the miscellaneous phenomena which we proposed formerly to treat, *phosphorescence* (φως, light, and φέρειν, to carry) holds the first place, under the supposition that the combustion of phosphorus at a low temperature gives rise, under certain circumstances, to luminosity. This effect has been sometimes said to arise from the absorption of oxygen gas in the air; but how far that may be true does not appear to be well ascertained. Professor Allman, remarking that the flowers said to be luminous are of a more or less orange colour, and that the phenomenon takes place in still, warm, summer evenings, towards twilight, is disposed to attribute it to optical illusion depending on a peculiar intermittency on the retina. Of this, mosses may perhaps be cited as an example, for light has been sometimes observed in them; but as this appearance is restricted to certain seasons, when the utricles of the species assume a globular form and become transparent, it arises from a refraction and reflection of the light on the surface of the vesicles. That in many other cases, however, the appearance is referrible to the real liberation of phosphorus from some of its combinations in the plant, appears to be placed beyond a doubt. It has been long noticed among the lower class of plants, particularly fungi, when they become developed in decaying wood; and most of our readers must be familiar with this spectacle in the putrescent branches or trunks of firs. Two species of luminose agarics, growing on the trunks of Banksia and Eucalyptus near the Swan river, are described by Mr. James Drummond. Delile found the Agaricus olearius near Montpellier to exhibit the appearance; and another observer says, that the Agaricus gardeneri of Brazil emits a pale greenish hue, similar to the light of fire-flies. The spawn of truffle (tuber cibarium) gives an effect of the same kind; and a species of rhizomorpha, infesting the coal mines of Dresden and other places, has been long celebrated for its phosphorescent properties, so constant and brilliant as to dazzle the eye of the visitor.

But a phosphorescent appearance has been traced among the classes of plants higher up than fungi. Linnæus was the first to record an observation on the subject among cultivated or garden flowers; and his daughter, Christina Linne, states that the flowers of Nasturtium, orange lily, and African marigold, at the end of a hot summer day, give out intermittent light. Mr. James, Mr. Dowden, and other observers, have renewed the same assurance; and the appearance has been witnessed by several of them whilst occupying different positions in regard to the Sunflower, French marigold, species of Oenothera and Arum. One, writing in the Gardener's Chronicle for October, 1843, relates, "I have frequently observed the luminous appearance of garden plants, and have looked for it in each succeeding summer on the double marigold, and more especially on the Papaver pilosum, the hairy red poppy, in my garden in Worcestershire. In the evening after a hot dry day, the flashes of light have afforded much amusement to myself and others." It is in allusion to such facts, that Coleridge has penned the lines,

"'Tis said, on summer's evening hour
Flashes the golden-coloured flower
A fair electric flame."

2. The *excitability* of plants has been sometimes called by the questionable name of irritability, and when instances of its operation are extreme, even by the title of *sensibility.* The contractions and changes which many plants exhibit, usually in connection with the hinge, proceed, obviously, from an accommodation betwixt external forces and an inherent vital action, and although in numerous instances their use is quite apparent, the exact stimuli by which they are excited escape beyond the reach of easy observation. "We plant," says Sturm (Reflections, ii. 102), "a shrub and destroy it, without finding any analogy between it and an animal that we bring up or kill. We see a plant bud, blossom, and bear seed insensibly, as the hands of a watch run round the points of a dial. The most exact anatomy of a plant does not unfold to us any organ which has the least relation to those of animal sensibility." They have nothing, indeed, in common with a nervous system, as that has been claimed by Martius, Meyer, and Darwin; and it appears to be the property of the chief organ of nutrition—the cellular tissue—"to take cognizance of the action of external influences upon it, and by which it resists those mechanical and chemical efforts which would otherwise soon succeed in decomposing its substance." (Henslow's Bot. p. 161.) Dutrochet (Sur la Matilité, Paris, 1824) was at first inclined to impute the sole effect to galvanic agency; but in his Nouvelles Recherches sur l'Exosmose &c., he somewhat alters his explanation of the manner in which galvanism, as the real agent, produces its result. The views of Morren are thus analysed by Balfour (Manual, &c., p. 661), in a reference of the alterations to the structural circulation of fluids and air. "In plants with irritable leaves, there are frequently swellings where the leaflets join the stalk as well as where the stalk joins the stem. These swellings contain cells which differ in their dimensions and contents, and the movements are considered as being produced by changes in the contents of the cells, some of which become more distended than others, and thus cause incurvation or folding. In these swellings the vascular bundles are disposed in a circle near the periphery, and may be concerned in the movements. Mechanical and chemical stimuli are supposed to act by inducing alterations in the contents of the vessels and cells."

The principle of excitability may be traced in many plants

under the influence of the ordinary elements, particularly of light and heat. In some of the cells of cryptogams, especially antherida, the bodies called phytozoa display temporary movements. Among the sea-weed class are some, comprising Vaucheria, Conferva, and Prolifera, the spores of which, when newly shed, Thuret and Decaisne found to keep the water in a state of constant agitation by means of their cilia or tentacula. In Chaetophora elegans, *var.* fusiformis, four of these motive organs have been seen determining by their vibrations the forward movements of the plant. But one of the most remarkable instances occurs in the Oscillatoria, the wavering movements of which were discovered by Adanson in 1753. These plants are filaments composed of cells, placed endwise, and filled with fluid and granular contents. They may be readily procured for inspection from their abundance in ditches, ponds, and damp places; and such is the rapidity of their growth, that their entire length is numbered by hours. The motions occur only in the young fibres, ceasing entirely after they are mature; but even a growing fibre placed upon a plate, turns itself backward and forward. In the water, they are seen to form a spiral like the letter S, from which they project to a straight line again; and they keep advancing under this repetition of forms, sometimes slowly, sometimes quickly, and not unfrequently in a jerking manner.

When we arrive at the phanerogamous classes, the fovilla of the pollen grain in its incipien tstate, as in great toad-flax or snapdragon, exhibits molecular movements similar, it is probable, to those produced by finely powdered gamboge suspended in water. A multitude of floral envelopes and compound leaves become folded at particular periods with a reference to the weather; such is the expansion of the petals of tulip or field marigold in fine weather, and their closing when the sun sets or rain falls. Wild oats warmed by the hand, move upon a table; and the Heliotrope, or sun flower, turns towards the sun. "Let a traveller seek shelter from the sun under an acacia with thorns white as ivory, called by Linnæus, Mimosa eburnia. The dark shade on the sand perhaps becomes suddenly dotted with light: he looks up and observes that his parasol is shutting itself up, and every leaf putting itself to bed. If he will look closely he may observe too, that the leaves sleep by the dozen in a bed, nestling together in small heaps. The traveller has nothing to complain about: he does not need the shade, there is a cloud over the sun. There is no reason why the whole roots of the tree should not be watered in the arid soil, nor why its leaves, delicately set on slender stems, should be beaten from their holdings. The leaves, therefore, are shut up and drawn together in small bundles, that they may find in union the strength which in isolation they do not possess; while, at the same time, room is left for the rain to pass between them to water the roots."—Household Words, No. 201, 1854.

A great range of plants, however, evince a capacity, not only to be affected by the elements, but by a kind of stimulation very distinct, namely, the touch; and the term sensitive plants is generally applied to this kind, in contradistinction to the general property of the tissues of plants, and especially of flowers, to be influenced by other external agents only. Among the various families that possess the power of moving under a slight touch, certain plants may be adduced belonging to the order Leguminosæ.

The Mimosa pudica, known in most seed shops as Humble plant, is a native of Brazil, and an inhabitant of tropical climates in moist districts, with a temperature of between 70° and 80° F. Every division of its stem is furnished with a leaf, composed of four partial petioles in pairs, extended from a common rachis, and each pair fringed with rows of leaflets on either side. The footstalks between the stems and leaflets seem the most irritable parts, and the effects are varied according as the touch is applied at different points of the structure. A depression of the whole leaf is followed by a touch, even though slight, on the lower side of the swelling, at the base of the petiole proper; but no corresponding impression is produced by a touch of the upper side of that swelling. There is a smaller swelling at the base of each leaflet, which, if touched on the upper side, causes the leaflet to move upwards; but a cautious manipulation of the lower side is not productive of the same effect. A touch of the leaflets at the extremity of a petiole causes the irritation to pass from that point in the direction of the base; whereas a touch applied to those at the base reverses this direction. A section of these swellings, examined under the microscope, shows a peculiar cell structure, which is probably the key to their solution.

During the day, in their undisturbed state, the leaflets are expanded; but when touched, each leaflet moves upwards, so as to come into contact in their upper surface, and to present the lateral view of an inner row only on the stalk, or like scales or tiles exposing the smallest portion of the surface. If the touch be continued, it causes the whole leaf to fall down towards the stem, but if removed, the plant gradually recovers its previous posture. It is a little singular, that the first application of touch is always the most palpable in its effects, for a long continuance of the irritation accustoms, as it were, the plant to bear it, and the leaflets ultimately expand. Darkness, wind, cold, or rain appress, in like manner, the upper surface of the leaves.

These phenomena are seen, to the greatest perfection, in the native country of the plant. A knock upon the ground, at a short distance, produces there a shock upon the leaves; and Von Martius affirms that at Rio Janeiro the tramp of horses' feet set whole lines of them in motion by the way. In this country, the conditions are most favourably displayed in young individuals, during clear warm weather, with a certain degree of moisture. The collapses are thus elegantly characterized by the author of the "Botanic Garden":—

> "Weak with nice sense the chaste Mimosa stands,
> From each rude touch withdraws her timid hands;
> Oft as light clouds o'erpass the summer glade,
> Alarmed, she trembles at the moving shade,
> And feels alive through all her tender form,
> The whispering murmurs of the gathering storm;
> Shuts her sweet eyelids to approaching night,
> And hails with freshened charms the rising light."

Hedysarum, changed by De Candolle into *Desmodium* gyrans, the moving plant of India, is a native of Bengal, near the Ganges, but grows luxuriantly in the gardens of Jamaica. The stem bears a petiole with a large leaf at the end, accompanied on the side by leaflets, and the whole are of a bright green, with the middle part more glaucous than the rest. No sooner, according to Linnæus, had the plants raised from seed by him acquired their ternate leaves, than they began to be in motion this way and that. This movement did not cease during the whole course of their vegetation, nor were they observant of any time, order, or direction. One leaflet frequently revolved, whilst the other, on the same petiole, was quiescent. Sometimes a few leaflets only were in motion; then almost all of them would be in movement at once. The whole plant was very seldom agitated, and that only during the first year. It continued to move in the stove during the second year of its growth, and was not at rest even in winter. Hufeland observed these motions very carefully, and gives the following account of them. The motion of the large terminal leaf is only observable during the influence of the sun's rays upon the plant, and during darkness hangs down. Early in the morning, the petiole forms an acute angle with the stem, and, as the sun's rays get stronger, the leaf which was previously dependent begins to rise. This goes on till noon, when the leaf and the petiole are on the same plane. As the sun declines, the leaf begins to fall, and the petiole approaches closer to the stem, till at last, when night comes on, the stem and petiole are parallel and embraced by the leaf, which cannot be separated without destroying its tissues. The passing of a few clouds over the sun will influence these movements considerably. They are best seen in hot weather and clear days.

The movements of the lateral leaflets consist of an alternate rise and fall. When the one is up the other is down. By the time the one has attained its lowest point, the other has attained its highest, and they both commence a contrary action at the same moment. These movements continue day and night, and in the hot native climate of the plant are pretty rapid.

Thus the motions are not produced by any accident, as in

the last case; on the contrary, they are entirely independent of mechanical stimuli. Incisions and maiming of the leaves have been found not to interrupt the gyrations, until desiccation began to ensue. The changes are only modified according to circumstances. In our climate at best they are exerted feebly and irregularly.

As we cannot afford to prosecute the illustration farther, the following list of examples is subjoined, each one of which will be found on inquiry to possess a high interest—Dionœa, Oxalis, Berberis, Stylidium, Mimulus, &c.

3. The *vitality* of plants means that retention of vital power which they possess. This power varies among different kinds. Melon seeds, for example, have been known to sprout after forty years, and the Sensitive plant has been mentioned as vegetating after sixty years. On the other hand, coffee seeds invariably spoil if long kept; and from the experiments of M. Adol. Decandolle on 368 species of seed, fifteen years old, collected at the same time, and sown out in the same circumstances, a portion is shown not to have come up at all.

Orders.	None vegetated in Species.
Scrophulariaceæ,	10
Umbelliferæ,	10
Caryophyllaceæ,	16
Gramineæ,	32
Cruciferæ,	34
Compositæ,	45

Those which are oily, from the chemical changes they induce, seem to lose their vital power early; and in general, a perfect maturity, uniform dryness, and enveloping in wax, sand, charcoal, or other medium, are essential to the *keeping* of seeds. A solution of chlorine has been reported as useful in decomposing their water and liberating oxygen.

The plants which are adopted for self-preservation or longevity, after lying buried deeply in the soil for long periods of time, have recovered from their dormancy on admission to light and air. Such are always to be seen springing up where forests have been burned, marshes drained, new soil excavated, or even thickets cleared. A great variety of interesting facts are on record as particular instances. The following extract is from the "Observations" appended to White's Nat. Hist. of Selborne, vol. ii., p. 255:—"The naked part of the Hanger is now covered with thistles of various kinds. The seeds of these thistles may have lain probably under the thick shade of the beeches for many years, but could not vegetate till the sun and air were admitted. When old beech trees are cleared away, the naked ground in a year or two becomes covered with strawberry plants, the seeds of which must have lain in the ground for an age at least. One of the sliders or trenches down the middle of the Hanger, close covered over with lofty beeches, near a century old, is still called Strawberry Slider, though no strawberries have grown there in the memory of man. That sort of fruit did once, no doubt, abound there, and will again when the obstruction is removed."

The seeds upon which the impress of vitality has fallen, include white clover, turnip, fumitory, and the farinaceous Buckwheats, Mallows, and Laguminosæ. Relations of mummy wheat have not been accepted without some measure of distrust and difficulty; but we cite the notice which follows from the prints of the day as a sample of the evidence by which that class of cases is supported. "Several years ago, the celebrated traveller, Sir Gardiner Wilkinson, presented the British Museum with an antique vase hermetically closed, which he had found in a mummy pit in Egypt, and the age of which was computed at about three thousand years. Mr. T. J. Petticrew, librarian of the late Duke of Sussex, proceeded to open the vase in order to ascertain its contents, but in doing so, unfortunately broke it in several pieces. The interior contained a mass of vegetable dust, with a few grains of wheat and vetches. He was, however, amply indemnified for the destruction of the vase, by discovering in this dust a number of peas entirely shrivelled and hard as stone. Mr. Petticrew distributed the grains amongst a few of his learned friends; but the grains rotted in the earth in which they had been planted. It happened, however, that Mr. Petticrew kept three grains for curiosity's sake, which, after the lapse of several years, he presented to Mr. W. Grimstone, the well-known inventor of the English eye snuff, and owner of the extensive Herbary at Highgate. Mr. Grimstone planted his peas on the 4th of June, 1844, in a pot filled with an artificial mould, resembling as nearly as possible the alluvial soil of Egypt, and placed it in a hot-bed under glass, where, however, there was but a moderate heat. After great care, Mr. Grimstone, at the end of thirty days, was rewarded by one of the peas coming up. In the next year, 1845, several of these grains were planted at once in the open ground, and succeeded completely. Subsequently, at a meeting of the Syro-Egyptian Society in London, Dr. Plate gave a lecture on the mummy pea, which he illustrated with dried portions of the plant, the blossoms, and grains, as well as with drawings. The blossoms do not resemble the wings of butterflies, as the blossoms of all other known species of *Cicer* do, but are bell-shaped, white, with green stripes, and issue from the sides of the stalks in clusters of from four to eight blossoms. The pods protrude through the blossom in the shape of a capital S; and as each plant produces several stalks, with sometimes upwards of a hundred pods, each containing from six to ten peas, the mummy pea is proportionately no less prolific than the famous Egyptian wheat, which was praised as a wonder by the ancient Greeks and Romans. The Egyptian pea is of the dwarf kind, wants no sticks for climbing up, and in its exterior most resembles the scimitar or marrow-fat pea. It is said to surpass in taste and colour every other species of pea."

The most vital point of a grown-up plant is situated immediately above the root, at the base of the stem or trunk. Injuries to this part always prove readily fatal; and instances are quite frequently seen of trees having died where the soil has been made to cover it.

4. The *diseases* to which plants are incident have been grouped according to their causes, and offer a large scope for sketching. They arise from natural derangements of the conditions of life, poisonous agents, the growth of weeds or parasitic feeders, attacks of insects, and mechanical injuries by other animals.

(1.) Diseases from natural derangements in the conditions of life. The Creator has ordained vegetable life to depend on certain organic laws. Under a healthy nutrition, every part is nourished by particles appropriate to itself; but in disease, foreign matters are admitted, and it is by their local influence that a morbid state is maintained.

Succulent tissues seem most predisposed to attack. Newborn parts, such as tender branches or young leaves, are required to part with their excess of fluid in the process of solidification; and to this function a regular humidity of the air and a certain temperature are necessary. It often happens, however, in our climate, from the prevalence of easterly winds in spring rendering the air so dry, that respiration is carried on with a rapidity out of pace with the supply of fluid obtained from the roots, and the tissues consequently become more or less infested with disease.

That light acts as a stimulus to plants is evident from common yellow goat's-beard closing its flowers about mid-day, on which account it is sometimes called *Jack-go-to-bed-at-noon.* It is easy therefore to perceive how an intensity of light may prove injurious to plants that live in the shade. Its deficiency again is the cause of a disease termed etiolation or blanching; and this state of the tissues is resorted to, to deprive some esculent leaves and stalks of their acrimony and cohesion, as celery, parsley, endine, succory, cardoon, sea-kale, and colewort.

Heat, in too great a degree, produces miliary sweat on vines. This consists of mucilaginous globules like millet seed perspired on the stems, and arises from their having been kept too close and warm in ill-ventilated hot-houses. What is called glazed corn (*bledglace*), presents a deep transparent yellow occasioned by the ripening having been precipitated by heats before the internal secretions of the seed were matured. Cold, on the other hand, is frequently prejudicial to leaves, stem, and flowers, as in the early shoots of ash, and the blossoms of apples and pears.

The superabundance or absence of drought is attended with

similar results. The first induces a dropsical state; that is, the juices become more aqueous than mucilaginous or saccharine, and the too luxuriant growth of the leaf-buds protracts the flowers, fruit, or seed. Drought, though it impairs the vigour of the leaf-bud, is said to ripen fruits and seeds earlier, with an increase of their grateful flavors.

There is reason to suppose that lightning occasions more damage to woods than is usually supposed.

The action of one or more of these causes generally terminates in blight—the popular name for any pestilence which curls up or destroys leaves and blossoms, or clothes them in black brown or a sickly yellow. A tract of wheat fields or hop plantations is commonly desolated about the end of July with us; and in the harvest, figures in an account of ricketty stems, empty ears, or shrivelled blades.

(2.) Diseases from poisonous agents which exist either in the atmosphere or soil.

The potato disease seems traceable to a miasma operating on predisposed tubers. A brown infectious matter was first observed to become deposited in the interior of the outer cells. The cell walls became afterwards disorganized; and the starch grains left open to attack, were soon confused in decomposing masses. The concluding act of this scene presented an assemblage of vegetable organisms preying among the ruins.

The artificially diffused exhalations most injurious to the life of vegetables arise from the smoke of lead furnaces, lime kilns, potteries, &c.

The earth itself, in which the roots of plants are inserted, is occasionally occupied with materials of a noxious nature to their absorbent system, as acid clays, causing the decay of the root fibres, and silicious sands without carbonaceous ingredients, impoverishing them, and exhaling the friendly dews and rain.

(3.) Diseases from the growth of weeds or parasitic feeders.

The most formidable weeds, from the exhaustion or shadow they occasion, are cockle or darnel, fox tail, wild poppy, wild vetch, dog's grass, colt's foot, melilot, thistles, &c.

During every stage of their growth, plants are liable to be invaded by minute parasitic feeders, whose sporules everywhere diffused through the air settle wherever a fitting indus is found. Spots of this character are especially apt to be formed on ripe fruits; and Professor Lindley of London has applied to these marks of decay the term *blets*. The constituents of ripe fruit, uniting with the oxyen of the air, form carbonic acid gas; and it is in that state of the organic elements the parasites are ready to be developed.

Smut balls, *pepper brand*, or *stinking rust*, is an attack upon wheat or other grain by the fungus called Uredo caries or fœtida. *Smut* or *dust brand* is a sooty powder upon the flowers of oats or barley, caused by Uredo segetum. *Red rust* or *rag* or *gum* or *robin* forms orange yellow or brown blotches on the inner chaff scales of corn plants, and indicates the presence of Uredo rubigo. *Mildew* is owing to Uredo linearis. *Ergot* in rye and other grasses is produced by a species of Spermædia. A species of Botrytis and Fusisporium solani have shown themselves of late of frequent recurrence in the potato. *Dry rot* in wood is the result of Merulius lacrymans, and sometimes of Polyporus destructor, as well as different kinds of Sporotrichum. Ravages are generally committed on a large scale by Fusiporium, Fusarium, Depazia, Sclerotium, Erysiphe, Oidium, Capillaria, Polyactis, &c.

(4.) Diseases from the attacks of insects. The list which follows, it is believed, will serve to begin the study of this department more effectually than any miscellaneous descriptions of more partial extent.

Insects	Injurious to	Description of Plants.
Carabus (Zabrus) gibbus,	Gibbous ground beetle,	Wheat, rye, barley.
Melolontha agricola,	Field cockchaffer,	Do. do.
Elater lineatus,	Click beetle, *Larva* wire worm,	Oats.
Agrotis (Noctua) segetum,	Dart or winter moth,	Oats and winter grain.
Agrotis (Noctua) tritici,	White-line dart moth,	Buckwheat and autumn-sown grain.
Botys (Pyralis) silacealis,		Millet.
Tinea granella,	Corn moth,	Grain laid up in magazines.
Curculio granaria,	Corn weevil,	Do. do.
Tipula tritici,	Wheat midge,	Wheat, &c.
Tipula cerealis,	Barley midge,	Barley and spelt
Coccinella impunctata,	Unspotted lady bird,	Artificial grasses.
Gryllus migratorius,	Migratory locust,	All vegetation.
Liparis (Bombyx) morio,	Ryegrass moth,	Meadow herbage.
Episema (Noctua) graminis,	Anther or grass moth,	Do. do.
Elator sputator,	Spring beetle or Skip-jack,	Lettuce, &c.
Lema asparagi,	Asparagus beetle,	Asparagus.
Haltica nemorum,	Turnip fly,	Turnip, cabbage, radish, cresses, &c.
Gryllotalpa vulgaris,	Male cricket,	Meadows, cornfields.
Papilio brassicæ,	Cabbage white butterfly,	Cabbage, radish, mustard, &c.
Noctua (Plusia) gamma,	Gamma moth,	Peas and fodder herbage.
Tinea (Hæmilis) daucella,	Carrot moth,	Carrots.
Tinea rosella,	Rosels tinea,	Spinach, strawberry, &c.
Anthomyia ceparum,	Onion fly,	Onion.
Tortrix (Cochylis) vitisana,	Vine moth,	Vine.
Forficula auricularia,	Earwig,	Carnations, pinks, dahlias.
Coccus hesperidum,	Orange scale insect,	Orange trees and greenhouse plants.
Aspidiotus rosæ,	Rose scale,	Rose trees.
Acarius telarius,	Plant mite or red spider,	Kidney beans, &c.
Papilio crategi,	Hawthorn pontia,	Hawthorn, &c.
Bombyx neustria,	Lackey moth,	Beeches, elms, poplars, &c.
Bombyx æsculi,	Wood leopard moth,	Horse chestnut, elm, walnut, pear, &c.
Bombyx cærulescephala,	Figure-of-eight moth,	Almond, apricot, peach, &c.
Geometra pilosaria,	Brindled beauty moth,	Pear, apple, &c.
Geometra defoliaria,	Mottled umber moth,	Lime, &c.
Curculio cupreus,	Copper-coloured weevil,	Plum, apricot, &c.
Scolytus destructor,	Elm-destroying scolytus,	Elm, fruit, and other trees.
Tenthredo morio,	Plum saw fly,	Plum, apple, pear, &c.
Aphis pyri mali,	Plant louse,	Apple, plum, peach.
Melolontha vulgaris,	May bug,	Oak, willow, hazel.
Bombyx bucephala,	Buff tip moth,	Oak, beech, birch, alder.
Bombyx pini,	Pine tree lappet moth,	Pines.

(5.) Diseases from mechanical injuries by other animals, such as field mice, rats, moles, hares, &c. The remote diseases arising from these injuries are gum secretion, sap-flow, and gangrene.

By way of supplement to this part of the subject, we may refer, in the words of a fascinating authoress of the western continent, to the reckless extermination, particularly there, with which "hills and vales are seen covered with stately and immense trunks, smitten down in every form and variety of misery. They lie like soldiers when the battle is done—in the waters, among the ashes, wounded, beheaded, denuded of their limbs, their exhumed roots, like *chevaux de frise*, glaring on the astonished eye."

"Man's warfare on the trees is terrible.
He lifts his rude hut in the wilderness,
And, lo! the loftiest trunks, that age on age
Were nurtured to nobility, and bore
Their summer coronets so gloriously,
Fall with a thunder sound to rise no more.
He toucheth flame unto them, and they lie
A blackened wreck, their tracery and wealth
Of sky-fed emerald, madly spent to feed
An arch of brilliance for a single night,
And scaring thence the wild deer and the fox,
And the blithe squirrel from the nut-strewn home
So long enjoyed."

"It seems almost a wickedness wantonly to smite down a vigorous healthful tree. It was of God's planting; in its veins are circulating the life which he has given. Its green and mighty arch are full of His beauty and power. It has borne winter and tempest without repining. Spring has dully remembered to awaken it from adversity, and to whisper that the time of the singing of birds hath come. War may have swept away armies, revolution overturned thrones, time engulfed whole races of men, but there it stood unmoved, unfaded, a chronicler of history, a benefactor to the traveller, a monument of the goodness of the almighty."

"Every echo of the axe doth hew
The iron heart of centuries away.
He entereth boldly to the solemn groves
Where nature in her beauty bends to God,
And, lo! their temple arch is desecrate;
Sinks the sweet hymn, the ancient ritual fades,
And up-torn roots, and prostrate columns mark
The invader's footsteps."

"The extirpation of the thicket from the field, where the bread for his household must grow, is of course a work of necessity. But a far reaching mind will spare here and there the time-honoured tree to protect the future mansion from the rays of the noon-day sun."

"Were our new settlers more frequently men of taste, this indiscriminate warfare upon the trees would be mitigated. They would realize how the lofty oak, beech, or sycamore, would adorn the dwelling which increased wealth might enable them to erect, or spread a blessed guardianship over the crystal stream, where the stranger might drink and rest, and thank God."

"The wild elephant, when death approaches, moves slowly to seek the shadow of lofty trees, and there resigns his breath. Intelligent man, like the most sagacious of animals, might surely spare a few, as a shelter for his weary head, and a patrimony for an unborn race. He might save here and there one solitary witness of His goodness who causeth those glorious columns of verdure to rise nearer and nearer to His heaven, while the heads of so many generations of men descend to the dust from whence they were at first taken."

———"Silent years roll on,
His babes are men. His ant-heap dwelling grows
Too narrow, for his hand hath gotten wealth.
He builds a stately mansion, but it stands
Unblessed by trees. He smote them recklessly
When their green arms were round him, as a guard
Of tutelary deities, and feels
Their maledictions. Now the burning noon
Maketh his spirit faint. With anxious care
He casteth acorns in the earth, and woos
Sunbeam and rain; he planteth the young shoot,
And props it from the storm: but neither he,
Nor yet his children's children, shall behold
What he hath swept away."

———"Oh Father! grant us grace
In all life's toils, so with a steadfast hand
Evil and good to poise, as not to mark
Our way with wrecks; nor when the sands of time
Run low, with saddened eye the past survey,
And mourn the rashness time can ne'er restore."
From Mrs. Sigourney's Scenes, p. 93, &c.

5. The *size*, *age*, and *duration* of plants, are points not only of general interest, but great practical importance.

In France and America, where forest trees attain a height of from 120 to 150 feet, the girth varies often from 25 to 30 feet and upwards. Maundrell measured one of the cedars of Lebanon, and found the circumference to be 36 feet 6 inches, and 117 feet in the spread of its boughs. The trunk of a dragon-tree of the Canaries has a girth of 45 feet; that of a maple in South Carolina, 62 feet; and baobabs have been found in Africa from 65 to 78 feet in circumference. A banyan growing lately on an island in the river Nerbudda in Hindustan, had, or still has, a circumference in its principal, though short, trunk of 2,000 feet; and this divides into 350 limbs, exceeding English oaks in thickness, and sending out above 3,000 smaller stems.

The age of plants varies with their class. There are races of *mucors* that are born and die in a day, while others increase their species and die after a few months. What are called annual plants have the production of their fruit and seed determined by a year, and are not capable of being prolonged beyond that period except by artificial means. Biennial plants are equally precise; only they extend to two years, germinating with leaves in the first, and flowering and seeding in the second. Perennial, again, is applied to the development of plants within a space not shorter than three years. "Under different climates, however," says Balfour, (Manual, ¶ 633) "and under different modes of management, the same species may be annual, biennial, or even perennial. Thus, wheat in this country is annual, if sown early in spring, but biennial, if sown in autumn; in hot climates, Lolium perenne proves annual. The castor oil plant in this country is annual, while in Italy it is a show of several years. The annual mignonette, by removing its flower-buds the first year, and, keeping it in a proper temperature during winter, may be rendered perennial and shrubby. Many flowering garden plants, as Neapolitan violet and lily of the valley, may be brought into flower at a late period of the year, by pinching off the blossoms in the early part of the season."

There is scarcely any well-attested evidence of the palm tribe and other endogenous trees acquiring a considerable age much beyond 300 years. It is of the exogens, or those whose increase takes place by the insinuation of longitudinal fibres beneath the bark, that remarkable cases of longevity are recorded.

———"Whose boughs are mossed with age,
And high top bald with dry antiquity."

Decandolle supplies the following list of ages, with a reference to ascertained individuals:—

Elm,	335	years.
Cypress,	350	"
Hand tree,	400	"
Ivy,	450	"
Larch,	576	"
Sweet chestnut, about	600	"
Orange,	630	"
Olive,	700	"
Oriental Plane tree,	720	"
Cedar,	800	"
Lime,	1076, 1147	"
Oak,	810, 1080, 1500	"

Of ancient yews in particular, many authentic instances are named. At Ankerwyke House, near Staines, is a tree of this kind, at three feet from the ground, measuring 9 feet 3 inches in diameter, and overshadowing with its branches a circle of 207 feet in circumference. It was growing in the time of the barons of Runnymede, 640 years ago. The ages of other yews have been computed as follow:—

Yew at Fountain's Abbey, Yorkshire,	1200	years.
Yew in Churchyard of Crowhurst, Surrey,	1450	"
Yew at Fortingall, Perthshire,	2500, 2600	"
Yew in Churchyard of Brabourn, Kent,	3000	"
Yew at Hedsor, Bucks, 27 feet diameter,	3200	"

The method of estimating the age of some of these specimens is two-fold—first, by comparing that which is unknown with the rate of growth in young trees that are known; and, secondly, by cutting out a portion of the circumference, and

Fig. 1.

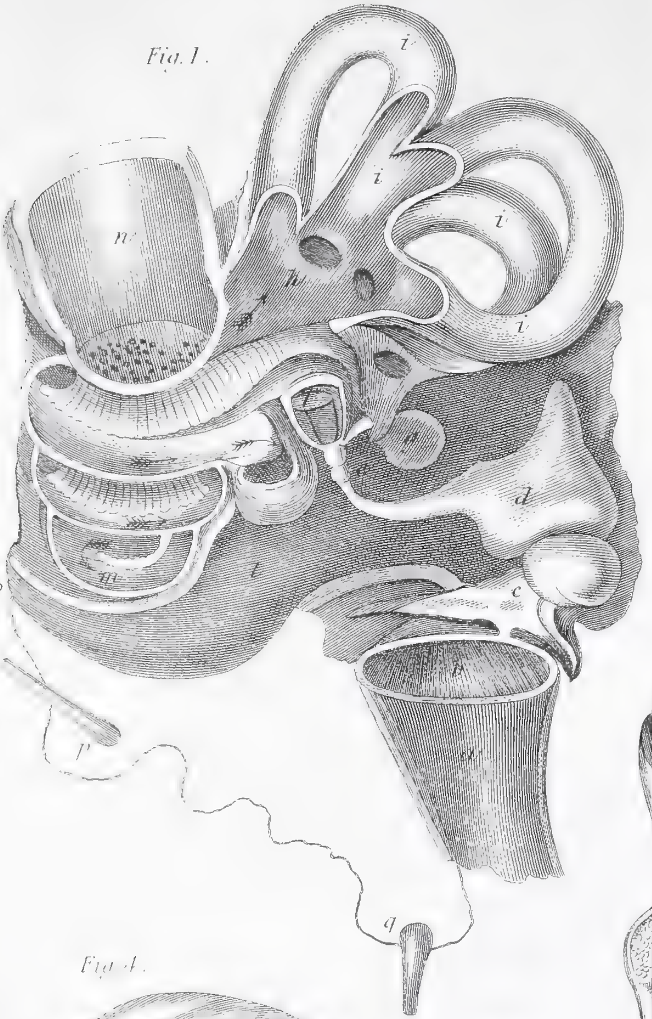


Fig. 2.

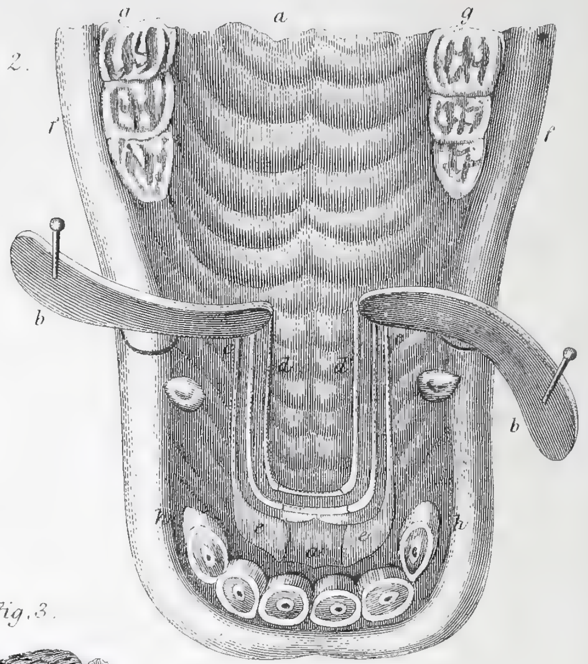


Fig. 3.

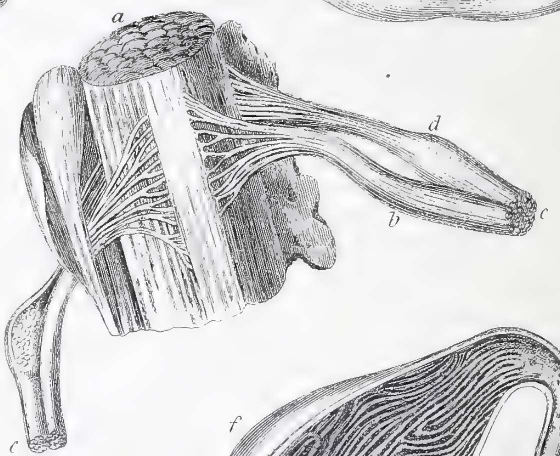
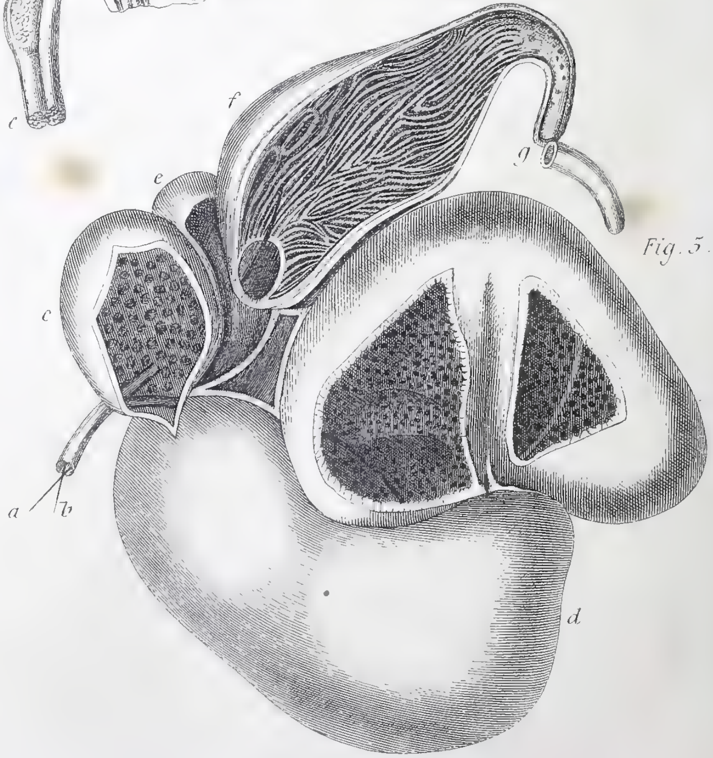


Fig. 4.

Fig. 5.



J. W. Lowry fc.

counting the number of concentric rings that mark the growth of separate years. But the one method is in a great measure conjectural, and only sufficient to give an approximation to the truth; and the difficulty of the other is often a drawback upon its accuracy. For it has been shown (Lindley's Introduction to Botany, p. 66), that in consequence of the inequality in thickness of the annual layers on opposite sides of a stem, a person, judging of a whole tree by an examination of the stinted side only, would commit errors to the amount of sixty per cent. and more.

The duration of wood after it has been cut, is regulated by the seasoning and temperatures to which it is exposed. Bichloride of mercury, chloride of zinc, sulphate of copper, creasote, and coal tar, have been severally used for its preservation.

FARRIERY.

CHAPTER VII.

THE SKIN OF THE HORSE AND ITS CONSTITUENT PARTS—THE INTERNAL ORGANIZATION OF THE HORSE—THE CHEST AND ITS CONTENTS.

The skin of the horse, like that of all other quadrupeds, consists of three parts, namely, the cutis, cuticle, and rete-mucosum. These differ from each other in appearance, texture, and organization.

The Cutis.—This is the true skin, which the tanner converts into leather. On some portions of the body this skin is attached so tensely, that hardly any motion is admitted of, while in others it is so loose that it admits of being folded. On the forehead, back, around the dock, and upon the pasterns it is so tightly braced, that it is hardly possible to pinch a portion between the finger and thumb. On the side of the face, the ribs, along the flanks, upon the arms and thighs, it will admit of being doubled; indeed, between the fore legs there are several natural semicircular doublings of the skin, for the purpose of preventing the action of the fore extremity from being constrained, and along the belly and flanks are other folds of a larger size, which give freedom of motion to the hind parts; moreover, wherever the panniculus runs, the skin is loose, otherwise that muscle could not possess the power of corrugation.

In the different breeds of horses there is a very considerable variation in the density or thickness of the skin, and even in different parts of the same individual. For example, what a contrast between the skin of the racer and that of the cart-horse! And there seems to be, in this respect, some connection between the cutis and the hair; for the skin as well as the coat of a black horse are coarser and thicker than those of a horse of the same breed of another colour; and it is rather uncommon to see a black race-horse, whereas the colour is nearly predominant among large, heavy, cart-horses. The skin is thinnest and softest in those parts that are either thinly covered with hair, or are quite destitute of it, such as the lips, nose, interior of the ear, borders of the eyelids, and the inward portions of the thighs.

The cutis itself is white; its apparent dark colour is derived from the rete-mucosum shining through it; this is sufficiently proved by those horses in whom that membrane is colourless; such as the cream-coloured, and milk-white racers; in pieballs, likewise, the skin appears white in places where the hair is white. But to prove that the cutis itself has no connection in colour with the hair, it will be found, that whether it be taken from a chestnut, bay, or black horse, when deprived of its fellow constituents, it will in every instance exhibit the same pale white aspect.

The Cuticle, epidermis, or scarf-skin, is a tough thin membrane without organization, and consequently divested of feeling, and serving only as an envelope to the true skin to protect it from injury, and defend it from the action of the atmosphere. It will be seen when blisters are applied, serum is effused from the exhalants of the cutis, and the cuticle becomes elevated by it into small round bladders, or blisters, and these manifest themselves through the semitransparent cuticle, and even the straw-colour of the fluid inside can be distinctly seen. The adhesion of the cuticle to the cutis, will be destroyed both in the living or dead animal, by the application of boiling water, as will also be effected by maceration in the lifeless subject.

The cuticle is continually growing, and the scurf which is brushed out in grooming are scaly portions of the cuticle, which appear to be composed of extremely thin flexible scales, somewhat resembling those of a fish, and similarly arranged. It is produced by the true skin, and is perforated by its exhalent and absorbent pores. Nearly over the whole body the cuticle is thickly covered with hair, but the lips, nose, interior of the ears, the borders of the eyelids, and inside of the upper portion of the thighs, are nearly naked, and the hair on those parts is much thinner in substance, than those portions which are thickly clothed with it. The cuticle is the same colour in all horses, with the exception of Arabians of a silver-grey, which is generally of a bluish-black. Whether this is produced by the rete-mucosum shining through it is not yet known.

The cuticle is devoid of sensibility, in consequence of having neither nerves nor vessels; the epidermis is every where perforated by minute holes, corresponding in situation, size, and number, to those of the cutis; namely, pores for the hairs, the perspiratory or exhalant pores, and the absorbent or inhalent pores; and likewise the larger sized pores for the emition of unctuous secretions.

The Rete-Mucosum is a fine, delicate, laminated tissue, which lies between the cutis and cuticle, answering as their connecting medium; so that in fact these two parts are nowhere in contact with each other. It is to this substance that the skin owes its colour, so that if either the cutis or cuticle of a black horse be examined, in its detached state, it will be found to be in itself perfectly colourless. The cutis vera of the Negro is as white as that of the European, the only difference being that of the skin being coloured by the rete-mucosum.

The Pores of the Skin.—These are spread over the entire surface of the skin, and in all probability they permit the passage of hairs through them. Besides the larger ones, there are innumerable others, which are very much smaller and less perceptible, and are termed the perspiratory pores, from their emitting what is called the *insensible* perspiration; the *sensible* perspiration is what is commonly called sweat. The situation of these pores is rendered manifest by the condensation and collection of this exhalation; but by the processes of maceration or putrefaction these pores can be rendered visible. There are another set of pores besides these, of larger dimensions, which in some places are more manifest than in others, and these are the mouths of follicles. In the nose these are of larger dimensions, for the secretion of mucus; and the tubes of the ears are provided with many of them for the secretion of waxy matter; and all the portions of the skin which are liable to friction are numerously furnished with them, for the purpose of preserving its pliability, and likewise of producing that greasiness of feel which is constantly kept up in the skin.

The process of perspiration in the horse cannot be kept under such control as in the human being by the use of medicines. The visible perspiration can only be increased to a limited extent in the horse, although in some degree that profuse perspiration which accompanies the moult may be checked; as also that which arises from want of condition.

As far as yet known, the visible perspiration cannot be induced by any kind of medicine, although we know that antimony and sulphur have considerable effect in opening the pores, and exciting the vessels to action to a certain extent. It is almost certain that the skin is provided with absorbent vessels, which take in any substance in a fluid state, and carries it into the circulation. The fact that the horse is easily salivated, even more so than the human being, is a conclusive proof of this. Salivation has been known to take place by simply rubbing a splint with mercurial ointment.

Of the Hair.—This consists of two qualities, one of which covers the entire surface of the skin, which is technically called its coat; the other is that which goes under the vulgar denomination of *horse-hair*, which is of a strong wiry texture, and is confined to particular parts of the animal, which nature has

provided more as an ornament and defence, than those of vesture and interception. For example, the mane acts as a shield to the neck in combat, and, consequently, is more luxuriant in the male than in the female, and the foretop, which is a continuation of the mane, is evidently provided as an ornament. On the other hand, the tail is not only highly ornamental, but also supplies the deficiency of hands, in switching off insects and other irritants within its reach, and which it wields with great power. The tufts of hair which spring from the fetlocks, defend those parts from contusion when forcibly depressed in action, and serve at the same time as a protection to the heels; and those filamentary hairs which invest the eyelids and muzzle are useful tangents of communication with the delicate organs of feeling into which they are implanted.

The coat is not of a uniform thickness or consistence on all parts of the skin. Upon the sides, back, loins, quarters, shoulders, and arms, it is thick and abundant, but upon the inner parts of the thighs, and under the arms, it is scanty and thin. Upon the genitals, udder, and anus, around the lips, and at the entrance of the ears, it is nearly as soft as down. It is longest and most abundant about the throttle and within the ears, and coarsest and most capable of resistance upon the legs. It varies in quality, colour, and length, in different breeds; and is, to a considerable extent, influenced in these particulars by climate. The Arabian, Barb, Turkish, and thoroughbred race-horses, have remarkably short and sleek skins; whereas the cart-horse, Shetland pony, as well as all those of Northern latitudes, are distinguished by the length, roughness, and coarseness of their hair. Colour seems also to have much to do with the texture of the hair of animals; it will generally be found that the lighter the colour, the finer the hair will be; and it has been remarked, that in the chestnut and light-bay horses, there are many more hairs in a square inch of skin, than in darker coloured horses.

The coat of the horse is shed twice a year, namely, in the spring and autumn. In a domesticated condition we find that the period is considerably influenced by the temperature of the stable, and management. But in a natural condition its periodical change is almost invariable as to time; the hair of the tail and mane is never shed. At the time when the animal is shedding his coat, there is a considerable loss of nervous power, and a general debility. He feels languid, and is frequently found bathed in profuse perspiration, with dullness of spirit. At those periods he should be subjected to as little labour as possible.

Veterinarians, during the moult have used stimulants to hasten the change; but these are apt to increase the fever which usually accompanies the shedding, and it is known that a general febral action has been induced; therefore it is wiser to allow nature to pursue its own course. Gentle friction with the brush will facilitate the process, but even this must be used with caution. Warmer clothing and moderate exercise should be adopted at this period. It will be found that during this state there is always an increased pulse, with a redness at the nose, and heat in the mouth. Many grooms at these periods are in the habit of administering cordials, mistaking febral excitement for debility. The stable-clothing should be warmer, and the ordinary quantity of oats should be diminished, and bran mashes should be substituted for hard food. The following alterative will be found to have a good effect.

Digitalis,	1	drachm.
Nitre,	2½	"
Emetic tartar,	1	"
Aloes,	1½	"

Colour of the Hair.—Hairs consist of a delicate process of a gelatinous or horny substance, which grows from a bulb situated in or beneath the skin; this bulb consists of a small cone-shaped body, which is composed of blood-vessels and nerves. It is on the surface of this bulb that the hair is secreted. The colour of the hair in most animals depends upon the chemical quality of the muscular fibre, as well as that of the circulating fluids; and it will be found that there is a general relation in colour between the skin, the hair, and the eyes. In horses with black hair, we invariably find the skin black, and the eyes usually of a deep hazel; on the contrary, in milk-white and cream-coloured breeds, the skin is white or colourless, and the eyes red, as in the albinoes of the human species. In brown, bay, and chestnut horses, the rete-mucosum participates of the colour of the coat; in pieballs, shewballs, and others, its colour varies in places with the change in the colour of the hair.

The three primitive colours in the hair of the horse are red, black, and white, and all the intermediate shades are modifications of these.

Reproduction.—When the hair is removed by any portion of the skin, it is speedily reproduced, because the cutis (and consequently the bulbs of the hair) remain uninjured; indeed, hair will be regenerated even after it has been picked out by the roots. In the case of broken knee, when it happens that the contusion is attended with destruction of the cutis, a scar or bald place must result; should a few white hairs make their appearance, we may reasonably conclude that they are the offspring of the injured (not totally destroyed) pulps.

The Lungs.—Plate IX., Fig. 1 *a*, *a*.

The lungs are two spongy substances, formed for the purpose of respiration; they are covered by a membrane called the pleura. They are situated in the sides of the chest, and are separated from each other by the mediastinum and the heart, which occupy the central region. They are so inflated during life, that they fill up every vacuity in the chest; no sooner, however, is a perforation made into the cavity of the chest, than they shrink in dimensions, and have all the appearance of being too small for the spaces they occupy. This arises from their being during life—or when the chest is unopened—in a constant state of inflation with atmospheric air, which keeps them expanded; and so soon as air is admitted, the pressure of the atmosphere upon them, from which they were before protected by the parietes of the thorax, they collapse in substance. Besides the division into right and left, they are further subdivided into lobes, called the right and left. The larger of the two is situate on the right side, and consists of three lobes, while that on the left has but two: these are, however, simply partial divisions of the lungs by clefts of variable extent through its substance, and which adapts them more thoroughly to fill the cavities of the chest, as also fitter for the purposes of expansion and contraction. The lungs of the horse, when inflated, are of much greater bulk, in proportion, than those of the human body. The reason why the right lung is the larger, is that the left has less space given to it than the right, from the heart being nearer that side. The lungs are attached above to the spine by blood-vessels, likewise to the divisions of the trachea, and the mediastinal portions of the pleura; all other portions of them are unattached and quite free. In form, the lungs are conical; being broad and concave behind, where they are opposite the convex surface of the diaphragm; narrow and somewhat pointed in front, where they are received into the blind pouches of the pleura, and are situate in the space between the two first ribs.

The speed and wind of the horse depend greatly upon the capacity of the lungs. In proportion to the quantity of air which they contain, the less frequent necessity of renewing that air by the act of breathing, will the animal be at his ease, or distressed when going at great speed. Consequently, one of the first things which a judge of a horse examines, is the capacity of the chest, and if the depth of the girth is considerable, and roundness behind the point of the elbow—the horse carrying what has been commonly called a good barrel—he is satisfied as to the capacity of the chest.

We may briefly state the office of the lungs. The blood, in its passage through the capillary tubes, contributes to the nourishment of the body, and furnishes all the secretions, and hence becomes changed in its quality, and is no longer able to support animal life, in consequence of having become too much carbonized, and which must be purified, before the blood can be usefully employed. That portion of the atmosphere called oxygen, which has a strong attraction for carbon, and unites with it whenever they come in contact, causes that deterioration of the blood. The chest enlarges by the action of the diaphragm, and the intercostal and other muscles, and the lungs expanding

with the chest, in order to fill up the vacuum which would otherwise exist between them and the sides of the chest, these cells enlarge, and a kind of vacuum is caused in each of them, and the air rushing down, fills them, and being divided from the venous and poisoned blood by these membranes alone, it is enabled to act upon the blood, and absorbs from it this carbon, and thus it is purified, and rendered arterial blood, and hence fitted for the purposes of sustaining life. This being accomplished, the chest contracts, and the lungs are pressed into smaller compass, and again a portion of air impregnated with carbon, and rendered poisonous in its turn, is squeezed out. Immediately an expansion of the chest again takes place, the lungs expand with it, and fresh pure air is admitted, which is soon pressed out again, empoisoned by the carbon of the blood, and these alternate expansions and contractions constitute what is termed the act of breathing.

During violent exercise, the animal requires a much larger supply of pure blood to keep up the more energetic action, and the action of the muscles drives the blood more rapidly through the veins, which produces that quick and deep breathing of a horse when galloping at speed. It is, therefore, evident that a capacious chest is indispensably necessary, so that it may yield an adequate supply; and hence the connection of the capacity of the chest with the speed and endurance of the horse. And it will be evident, what wonderful relief is afforded to the animal by loosening the girths, when it is blown and panting, by enabling the chest to expand and contract freely, and thus a greater quantity of purified blood is produced, and relief afforded, even by a very short period of rest.

Although the cart, waggon, or dray horses are not subjected to rapid movements, yet a capacious chest is of much consequence to them, because there is in them a large accumulation of both flesh and fatty matter, which require a large portion of blood to supply their growth.

In the horse, lung diseases are common, and among the worst to alleviate, and they, consequently, render them unfit for useful service. Indeed, it is cruelty to work the poor animals at all, when labouring under complaints of this category. It is in vain to treat such cases medically, as there is no chance of effecting a cure.

Most lung diseases are brought on by being overheated, and frequently not being rubbed down, and are likewise often left in a wet condition in cold and damp stables. No horse should be left to dry in profuse perspiration, but ought to be rubbed until they are quite dry.

THE HEART.

This organ is of a conoid form, with its base turned uppermost. Its situation is opposite the 4th, 5th, and 6th vertebræ of the back, from which it is suspended in its situation in the middle of the cavity of the chest, by the attachments of the venous and arterial trunks, immediately connected with it. Its apex hangs loose and unattached within the cavity of the pericardia, with the point inclining downwards and backwards towards the left side.

The heart is the organ by means of which the blood is circulated through the body. It is composed of four cavities, two of which are above, and are designated auricles, from their similitude to the ears of a dog; and two ventricles, two little bellied processes which occupy the substance of the heart. After the blood has circulated through the frame, and nourished it by the arteries, it returns to it through the veins, and enters the auricle on the right side of the heart, where it accumulates as a reservoir, until it is sufficient to fill the ventricle below; the auricle then contracts, and forces the blood into the ventricle, which, in its turn, contracts and drives the blood, not again back into the auricle, which, to prevent this, is provided with a valve as complete as the sucker of a pump, but through an opening which leads into the lungs. The blood traverses the numerous small vessels and cells of the lungs, where it undergoes an important change, and is then conducted to the left auricle; thence it descends to the left ventricle, and by a powerful closing of the ventricle is forcibly propelled into the arteries; the first of which is the aorta, which rises from the left ventricle, and this sudden contraction of the ventricle gives it a force which, assisted by the elastic power of the arteries, keeps them open and free from obstruction, and likewise by the pressure of the muscular and elastic coats, endeavouring to return to their former dimensions, pursues its course through every part of the animal frame.

The heart sympathises with the diseases of all parts of the frame, and is itself subject to several maladies. Even an inflammation in a foot will affect the beating of the heart, and will often raise the pulse to double its ordinary beating. Inflammation of the heart itself is a complaint to which the horse is liable, and which is induced by sympathy from other portions of the body. This complaint is a most dangerous one, and is frequently so manifest that a bounding of the heart may be occasionally seen on the left side, and even its beating heard at several yards' distance, occasioned by the quick and strong pulse. The horse, under this complaint, exhibits a peculiar alertness and rapidity of action, and a very peculiar expression of energy in the countenance.

THE ABDOMEN AND ITS CONTENTS.

The diaphragm, Plate IX., figs. 1 and 2, and Plate X., fig. 1, separates the abdomen from the chest, which extends obliquely from the loins to the breast-bone. In its natural condition, it is convex or projecting forward towards the lungs, and concave or hollow backwards towards the stomach and intestines; on the side towards the chest, it is covered by the membrane which envelopes the lungs, and towards the abdomen by that which invests the intestines. It is attached to the spine, the ribs, and breast-bone, by tendinous or fleshy expansions, and in the centre by strong muscular fibres. No muscle in the frame is of more importance than this. It is one of the chief agents in the process of breathing. During action, its fibres are shortened; it is divested of its convexity, and becomes plane; the chest, consequently, becomes enlarged, and the lungs enlarge with the expansion of the cavity in which they are situate, the air rushes in, and inspiration is performed. So soon as the fibres of the diaphragm cease to act, that muscle returns to its natural form; but again becoming convex, it presses upon the lungs, and assists in forcing out the air, and expiration is accomplished; and it likewise lends its aid in the constant motion of the bowels, and by means of its powerful effect, it expels the fæces and urine, and in the female assists in expelling the young animal, during parturition.

The membrane which covers the diaphragm is very subject to inflammation, and symphathises with the diseases of contiguous parts, such as complaints in the lungs and bowels. It soon becomes inflamed and irritable, and thus the breathing in the horse is so much affected when labouring under any inflammation in the chest or belly. Violent exertion, likewise, frequently occasions rupture of the diaphragm, which has so much work to perform in the act of breathing, and no wonder that it frequently gives way. There is no malady to which the horse is liable, so difficult to ascertain as rupture of the diaphragm. There is no symptom on which implicit reliance can be placed. However, a short space of time will too certainly develop the fact, as it always proves fatal. In the case of a small rupture, a portion of the intestines insinuates itself, and becoming entangled, thereby causing an irremoveable obstruction; and if the opening be large, so great a portion will pass through as will press upon the lungs, and render respiration impossible, and cause immediate death.

THE STOMACH OF THE HORSE.

PLATE IV., FIG. 4.

The stomach is situate on the left side of the abdomen, and rests upon the large intestines, with its fore part close to the liver, and its left side in close contact with the diaphragm. The position occupied by the stomach renders it manifest, that to work a horse hard after having been fed must be oppressive to him, and, in many cases, is attended with fatal consequences. Every contraction of the diaphragm, or inspiration, displaces and drives back the stomach, consequently, in proportion to the fulness of the stomach will be the weight to be overcome by the diaphragm, and, therefore, the exhaustion of the horse. The stomach being too much distended, renders it too

weighty to be pressed far enough back to make room for the quantity of air which is required by the animal when in the act of exerting itself. This will be evinced by the quick breathing arising from this cause, and which often produces death. While on a journey, therefore, great caution should be observed as to the quantity of food given him, which should be limited to a half feed, or even less, and rather let it be given at shorter intervals. If a horse is to be hunted, let the animal be fed an hour before starting for the field, and he should not be allowed so much water as he will drink.

Nature seems so far to have guarded against the danger to which a horse is likely to be exposed, by providing him with a smaller stomach than most other animals of his size. In short, it is not half the size of that of man, in comparison to his size; and, what is still more striking, the food required for the sustenance of the horse occupies a space ten times more in bulk than the food of the human being.

A reference to Plate IV., fig. 4, will give a tolerable idea of the different parts of the stomach.

a, The œsophagus, or gullet, the passage through which the food passes from the mouth to the stomach.

b, The opening through which the food passes into the stomach. The circular layers of the muscles are very thick and strong, and, by their contractions, contribute to render it difficult for the food to be returned or vomited by that animal.

c, c, That portion of the stomach which is covered by cuticle, or insensible skin. In this respect it differs from all other quadrupeds, save those of the graminiverous monogastric kind, and which may be reckoned its third coat. Numerous small openings are observable on its inner surface for the exudation of a mucous fluid, which assists in the process of digestion.

d, d, The margin which separates the cuticular from the villous or velvet-like portion. It is here that the operation of digestion properly begins. The orifices of numerous small vessels open upon it, pour out the gastric fluid, and mixes with the food which has been softened, and converts it into a fluid substance termed chyme; and as this is formed it enters the other orifice of the stomach, called the pyloric (or door to guard), at *f*, where it is conducted to the first small intestine. Those portions of the food which are undissolved, are turned back to undergo further grinding action.

e, e, The mucous or villous (velvet-like) portion of the stomach, in which the food is chiefly digested, as described above.

f, The communication between the stomach and first intestine.

g, The common opening through which the bile and the secretion from the pancreas pass into the first intestine. The two pins in the figure show where the two tubes unite.

h, A smaller orifice through which a portion of the secretion of the pancreas enters the intestines.

THE LIVER.

Plate IX., Figs. 1—6.

The liver is the largest gland in the body; its function is the secretion of bile. The greater portion of it is situated in the right hypochondriac region, although some part of it is placed in the epigastric, and a small portion extends between the stomach and diaphragm, into the left hypochondriac region.

As already stated, the blood which has been conducted to the different parts of the body through the arteries, is carried back to the heart by the veins; but that portion of it which is returned from the stomach, intestines, pancreas, spleen, and mesentery, in place of flowing directly to the heart, passes first through the liver, and in traversing this organ a fluid is separated from it, which is termed the bile. The bile acts a prominent part in the process of digestion, by changing the nutritive portion of the food from chyme into chyle, and dividing it from that which contains little or no nutriment, and is voided as excrement. The bile is received into a small receptacle in man and in most quadrupeds, called the gall bladder, from whence it is conducted into the duodenum, *o*, in such portions as is required for the purpose of digestion; but the horse not being provided with a gall bladder, and therefore the bile flows into the intestine as quickly as it is separated from the blood. The utility of this is evident, because the horse being provided with such a small stomach, that the food might quickly pass out of it, and the diaphragm and the lungs might not be pressed upon, and impede their action, when he required their full play while going at full speed, and that he might be used with as little danger, compared with that which would attach to other quadrupeds, even when his stomach is distended with food. The stomach of the horse being so small, and, consequently, so soon emptied, requires to be more frequently replenished with food, so that there is no necessity for a gall bladder. Horned cattle occupy a much longer time in feeding than horses, and it is only when they are ruminating, or what is called "chewing the cud," that the food passes from the paunch into the true stomach to be digested. The dog, cat, and other carniverous animals feed rapidly, and the process of digestion is very slow, so that they require a gall bladder to contain the bile, which continues to be secreted when it cannot be used; but to the horse, that is so frequently eating, it would be of no use.

THE OMENTUM OR CAWL.

The omentum invests the lower part of the stomach. It is small in the horse, and seldom contains much fatty matter. It consists of four layers of the pèritoneum, two of which are derived from the stomach, and two from the colon. (Plate IX., fig. 1, *c*.) It is supposed to be placed between the intestines and sides of the belly, to prevent concussion and injury during rapid movements.

THE MESENTERY.

The small intestines are loosely connected to the spine by a duplicature of the peritoneum, denominated the mesentery; the colon is attached in like manner to the bone by a production of the same membrane, called the mesocolon; and the rectum is confined in its place by a similar reflection.

THE SPLEEN.

This organ is situated on the left side of the stomach, fig. 1, *e*, lying there between the concavities of the false ribs, with the back cartilages of which its margin lineally corresponds, so that if the belly were pierced from the left side posteriorly to the last rib, the spleen would escape injury. It is attached to the left half of the great curvature of the stomach, but the greater portion of it lies behind and rather above the stomach. Its anterior end lies in contact with the left lobe of the liver; its posterior is attached to the left kidney, and concealed by the windings of the colon. Its true use is unknown.

THE PANCREAS.

Lies between the stomach and the left kidney; it has a strong resemblance to the salivary glands, and secretes a fluid much like saliva, which is conducted into the intestines by a duct which enters at the same opening as that from the liver. Its use has never been properly understood, but is supposed to assist in the digestive process.

THE KIDNEYS.

The kidneys are two organs of a pale red colour and firm consistence, in form resembling the beans which bear the same name. The right kidney is situate most forward, lying under the liver; the left is pushed more backward by the stomach and spleen. To each of them a large artery runs, conveying not less than a sixth part of the whole blood that circulates through the animal. This artery divides into innumerable small branches, most remarkably complicated and coiled upon each other; and the blood traversing these convolutions has its watery parts and others separated from it, which would prove injurious to the constitution, and would act as a poison. Plate IX., fig. 1, *g, g*.

THE URETER.

Is that tube which conveys the urine from the kidney into the bladder, and emanates from the posterior end of the pelvis.

THE BLADDER.

The bladder is situated in the middle lower regions of the

pelvis, taking the oblique axis of that cavity, and placed upon the *symphysis pubis*, with the rectum above it in the male, the vagina in the female. When the bladder is empty, or nearly so, it is entirely confined to the cavity of the pelvis; but when full, its fundus advances before the pubis into the abdomen, the advancement being, of course, in proportion to the degree of distension.

When the urine separated by the blood is discharged by minute vessels into some larger canals, which end in a reservoir in the internal portion of the kidney, which is termed its pelvis; and thence it is conveyed by the ureter into the bladder. It is constantly flowing from the kidney through the ureter, and were there no provision for its detention, it would form a constant annoyance by a continuous flow. The bladder terminates in a small neck, round which is a strong muscle, keeping the passage closed, and retaining the urine until, at the will of the animal, or when the bladder gets nearly filled to its utmost capacity, the muscular coat begins to contract, and the lungs being filled with air, the diaphragm is rendered convex towards the intestines, and presses them on the bladder, when, by their united powers, the fluid is forced through the sphincter muscle, or neck of the bladder, and escapes.

THE INTESTINES.

Plate X., Fig. 2.

When the food has been partially digested in the stomach, and converted into chyme, it passes through the pyloric orifice into the intestinal canal.

The intestines are of a cylindrical form, but very unequal in their circumference, and forming one continuous convoluted canal from the stomach to the anal termination. They are separated into the following portions:—

a, The beginning of the small intestines. The ducts which convey the bile and secretions from the pancreas, are observable entering a small way below.

b, b, b, The convolutions of the small intestines terminating in the cæcum.

c, c, The cæcum, or blind gut, with the bands crossing and dividing it into numerous cells. It is so denominated from there being no opening through it, being stopped at one extremity, consequently, all the food which enters it must reascend into the *caput coli*, in order to be conducted through the intestine.

d, d, A portion of the mesentery, which is a duplicature of the peritoneum. The colon is likewise attached to the bone by an elongation of part of the same membrane, which is termed the mesocolon, and the rectum is kept in its position by a similar reflector, termed the mesorectum.

e, e, The commencement of the colon.

f, The termination of the colon in the rectum.

g, The termination of the rectum in the anus.

The intestines of a full-grown horse are ninety feet in length, being from eight to nine times the length of his body.

Plate X. Fig. 3.

The subject here represented is to illustrate the relative position of the principal organs, with only a portion of intestinal canal. These are situated exteriorly to other important viscera.

a, a, a, The various lobes of the lungs.

b, The pericardium, or bag which envelopes the heart.

c, The heart.

d, d, d, The colon.

e, The ligamentous bands of the colon, which pucker it into folds.

f, f, f, The ribs.

g, The sternum or breast-bone, removed and thrown back to show the contents of the chest beneath.

h, The diaphragm already described.

i, i, i, i, The skin thrown back to exhibit the contents of the chest.

j, One of the small intestines.

k, The ensiform or sabre-shaped cartilage.

l, l, The neck.

m, The windpipe, or trachea.

Plate IX., Fig. 1.

The principal organs shown in this figure are mostly hidden by those described in the last figure.

a, One of the lobes of the liver.

b, The stomach.

c, The omentum or caul.

d, d, The kidneys.

e, The spleen.

f, The uterus, or womb. This is a hollow membranous organ, united to the anterior part of the vagina in the female, the form of which in the mare is very peculiar. Its body spreads out anteriorly into two horn-like protuberances. The vagina is bottle-shaped, and the uterial portion is like a head and neck. This shape is peculiar to the female which has not had a foal, but after gestation, it becomes much enlarged in size, and never afterwards contracts to its former dimensions.

g, g, The ovaries, which are two egg-shaped bodies, placed a little farther back than the fallopian tubes, within the cavity of the abdomen.

h, Part of the rectum.

i, i, The diaphragm.

k, The bladder, distended with urine to show its dimensions and figure.

l, The gall duct.

m, The duodenum, which is followed by the jejunum. The food passes through this organ very rapidly. Its colour is paler, and its calibre much larger than the duodenum; this is followed by the ileum, which is the longest of all the intestines, and forms the greater part of the convoluted tube, which mostly lies near the navel. The small intestines are capable of holding about eleven gallons of fluid matter.

The jejunum follows the duodenum; it is a portion of the small intestine. It passes through this with much rapidity, as in the dead subject this is always found quite empty. It is less in calibre and paler in colour, and of greater length than the duodenum.

Then follows the ileum, which is the longest intestine; it lies in the region of the umbilicus, or navel, and forms the greater part of the convoluted tube.

That portion of the food which has not been taken up by the lacteals and absorbents, while passing through the small intestines, is carried through the valvular opening of the ileum, and the fluid portion takes its course to the cæcum, where it remains a considerable time, so that the nutritive portion may be extracted from it. The cæcum is well provided with blood-vessels and absorbents, whose office is to carry off the nutritive portion of the aliment.

Horses sometimes drink more than their stomach is capable of containing, which passes on to the cæcum, and it acts as a reservoir in time of need. This organ will contain four gallons of water.

n, n, n, The aorta, or great artery, which descends in both cavities.

o, The vena cava descendens.

p, p, The emulgent veins, which discharge their blood into the vena cava.

q, q, The emulgent arteries, which take their rise from the aorta.

r, r, The spermatic arteries and veins, which are united by a cellular substance soon after their origin is distributed to the ovaria.

s, s, The ureters, which have their origin in the kidneys, and are inserted into the upper part of the bladder.

t, t, The iliac vessels, which are fork-shaped portions of the aorta and vena cava.

The length of the intestines of an adult horse is ninety feet. In different animals, their length is suited to the kind of food on which they subsist. The nutritive matter is with much more difficulty extracted from vegetable than from animal substances; consequently, the alimentary canal is large, long, and complicated in those which, like the horse, feed on herbs alone. The small intestines are about sixty-six feet in length, and the large, twenty-four. The duodenum is so called, because it is about twelve inches long in the human being, but in the horse it is nearly twelve feet in length.

CONCHOLOGY.

CHAPTER IX.

GRAND DIVISION II.

Ligament not marginal, but placed in a short hollow under the beak, always perceptible, and not forming a tendinous chord beneath.

TRIBE I.—OSTRACEA.

Ligament placed either interiorly or nearly so; shell irregular in form, foliaceous and sometimes papyraceous.

SUBDIVISION I.—Ligament placed interiorly; shell thin, papyraceous.

Genus.—ANOMIA.—*Linnæus.*

Generic Character.—Shell inequivalve, irregular, operculated; under valve flattened with a large circular or ovate perforation near the hinge, and its edges turned back, through which protrudes a testaceous, or bony, straight, elliptical operculum or plug, with a dilated base, by which the shell adheres to extraneous bodies; upper valve the larger, concave and entire; ligament large, transverse, internal, placed within the upper valve, at the umbo, and attached to a prominent, expanding appendage in the depressed valve; lower valve with a single, orbicular, nearly central muscular impression; upper valve with three impressions, situated contiguous to each other, the largest is next the base of the shell, which is connected by means of its muscle, with the plug, and the other two are also connected, by the medium of their muscle, with the single impression in the lower or flattened valve.

Anomia lineata. Plate VII. fig. 35.

The Anomiæ are liable to considerable modifications of form, depending upon the shape of the substance to which they are attached. But, although the lower valve is in close juxtaposition with such substance, yet it does not adhere to it, but is attached simply by the testaceous plug or operculum. This appendage seems to be a testaceous prolongation of the abductor muscle of the animal. The shells of this genus will at once be distinguished from the *Placuna* and *Terebratula* by the structure of its hinge and very peculiar muscular impressions, and neither of these genera have a perforation near the hinge, as in the Anomiæ.

The species are limited in number, and inhabit the ocean; they are met with in almost all climates.

Anomiæ are rare in a fossil state, and occur in the marine formations above the Chalk in France, and the Crag and London Clay of England.

SUBDIVISION II.—Ligament semi-interior; shell foliaceous, frequently very thick.

Genus.—VULSELLA.—*Lamarck.*

Generic Character.—Shell longitudinal, equivalve, subirregular; beaks equal, somewhat separated; between these lies the useless and decayed remains of the ligament; valves united at the hinge by a semi-internal ligament affixed in each valve to a subtriangular tripartite disc, one of its points reaching close to the beak, and a little inclined to one side; its central portion hollow and forming a projecting callosity within the shell, with the chief part of the ligament attached to this conical hollow; each valve is provided with a single lateral muscular impression, which is oblong and contracted towards the base.

Vulsella deperdita. Plate VII. figs. 29, 30, 31. Found fossil in the Calcaire-grossier at Grignon.

The Vulsellæ differ from the Crenatulæ chiefly in the hinge being provided with only one callosity, while there are many in *Crenatula.*

Sometimes the species of this genus gape posteriorly. They are but few, and inhabit the ocean, chiefly the Indian seas; and one is found in New Holland.

Genus.—OSTREA.—*Linnæus.*

Generic Character.—Shell inequivalve, irregular, and foliaceous; umbones somewhat separated, and of unequal size; lower valve largest, concave, and adherent; upper valve smallest, and somewhat plain; hinge destitute of teeth; ligament partly external; the facet to which it is attached is subtrigonal and tripartite, and is divided by two elevated lines which divaricate from the umbo; each valve provided with two muscular impressions, the one large, suborbicular, and nearly central; the other very small and situate near the hinge.

Ostrea gigantea. Plate VII. fig. 34.

All the shells of the genus *Ostrea* are of a laminated foliaceous structure. These laminæ are composed of perpendicular fibres; the points of the umbones are always apart from each other, and in some instances very remote, becoming more distant and unequal by age. The lower valve is always the largest of the two, and generally the most concave; and in the young condition they usually adhere to marine bodies. There are, in many species, a series of small denticulations situate near the hinge, which, however, cannot properly be considered as teeth. The ligament can only be reckoned as subexternal, although it is always concealed when the valves are closed; it is invariably placed in a subtriangular tripartite disc, one of its angles being always close to the umbo, from which diverge two somewhat elevated lines.

Section. 1. With simple margins, or slightly undulated; as in the *O. gigantea.*

Section. 2. With the margins plicated, as in *O. carinata.*

There are several genera which may be confounded with this, as follows: *Crenella* and *Perna* have a series of longitudinal grooves; *Pedum* and *Malleus* are invariably attached by a byssus, while the *Ostrea* adhere by the external surface of their shells; *Lima* and *Pedum* are always regularly formed bivalves, and attached by a byssus, the *Vulsellæ* adhere by their hinge, and are usually found enveloped in pieces of sponge; besides the central portion of the hinge in the Vulsellæ forms an internal projecting callosity.

The *Ostreæ* are marine shells, and are met with in all climates.

Fossil species are numerous, but difficult to make out.

The *Ostrea pulchra* is found in the Plastic Clay, and *O. deltoida*, characterises the Kimmeridge Clay.

M. Gerard, who traversed the snowy mountains of Thibet, in May, 1830, met with fossil shells at the amazing height of 16,000 feet above the level of the sea, and in reference to those of this genus, he says, "Just before crossing the boundary of Ludak into Brussalier, I was exceedingly gratified by the discovery of a bed of fossil oysters clinging to the rocks as if they had been alive. In whatever point of view we are to consider the subject, it is sublime to think of millions of organic beings lying at such an extraordinary altitude, and of vast cliffs of rock formed out of them, frowning over the illimitable and desolate waters, where the ocean once rolled."

Genus.—EXOGYRA.—*Say.*

Generic Character.—Shell inequivalve and unequal sided, attached to extraneous bodies; umbones spirally turned to one side; pit of the hinge curved and nearly linear; the flat, free valve, provided with an obtuse tooth, which fits into a cavity parallel with the hinge pit in the convex attached valve; each valve furnished with one muscular impression.

Exogyra conica. Plate VII. figs. 32, 33. Found at Blackdown, Parham Park, Chute Farm, and Warminster.

The shells of this genus are distinguished from those of *Ostrea*, which they somewhat resemble by their impressed lateral spiral umbones, and the consequent linear form of the hinge pit, and by the parallel furrow in the attached valve, which receives the opposite striated tooth. It differs also from Gryphæa, being devoid of the lobe of that shell.

Genus.—GRYPHÆA.—*Lamarck.*

Generic Character.—Shell free, inequivalve, upper valve small, flat, and acting apparently as a lid to the under one, which is large, concave, and arcuated; with an incurved prominent umbo; hinge destitute of teeth, with a curved depressed area; provided interiorly with one muscular impression.

Gryphæa incurva. Plate VII. fig. 36.

This species is found in the Lias of Yorkshire, and South of England, various parts of Scotland, and in the inferior Oolite of France and Germany. The shells of this genus are extensively scattered through different rocks of the Cretaceous group,

namely, upper and lower Greensand, Speeton Clay, and Chalk of all countries, as well as in the rocks of the Oolitic series.

The genus is only known in a fossil condition. The species have a considerable affinity to the Ostræa, but are at once distinguished by their more regular form, and remarkable curvature of the beak.

TRIBE II.—PECTINIDES.

Ligament placed interiorly, or partly so; shell in general regular, compact, and not foliaceous.

Genus.—SPONDYLUS.—*Linnæus.*

Generic Character.—Shell, inequivalve, subirregular; umbones unequal, and distant, separated from each other by a triangular, flat area, and provided with small auricles on each side; hinge of the lower valve with two very strong and greatly recurved teeth, separated by a deep central pit, which is the termination of a groove emanating from the point of the flattened area; this pit is for the reception of the ligament; and two lateral hollows for receiving the teeth of the upper valve; the hinge of which is furnished with two strong reflected lateral teeth, and two intermediate cavities for receiving the teeth of the lower valve; the ligament pit is in both valves, and the ligament is for the most part internal, but is also external; muscular impression single, suborbicular, and somewhat lateral; the parallel impression being continuous with and surrounding the other.

Spondylus crassicosta. Plate VII. fig. 43. *S. truncata*, fig. 41.

The Spondyli are marine shells, and inhabit the warmer portions of the globe; they are conspicuous for the beauty of their colours, and their remarkable forms, which are generally somewhat irregular, and usually attached to marine bodies. Their external surface is invariably rough, and clothed with spines or foliations. The upper valve is always more intense in its coloration than the lower one.

The teeth of the lower valve are so much arcuated, and inserted so peculiarly into their receiving sockets in the opposite valve, that it is impossible to separate the valves without either breaking them, or the margins of the pits. Although the ligament appears to be entirely internal, it is in fact also partly external, which portion is but very slender, and attaches the valves to each other along their linear margins.

Fossil Spondyli are rare, and occur in the Blue Marls, south of France, and in the Supercretaceous rocks of Bordeaux and Dax.

Genus.—PLICATULA.—*Lamarck.*

Generic Character.—Shell irregular, inequivalve, and destitute of ears, attenuated at the base, rounded and plaited at the upper margin; umbones unequal and entire; hinge with two strong, generally perpendicularly grooved teeth in each valve, with their points recurved, and a central cavity or pit for the reception of the ligament, which is internal; under valve generally more convex than the upper one; muscular impressions strong, orbicular, and situate near the centre of the valves.

Plicatula spinosa. Plate VII. fig. 37. *P. Pectinoides*, fig. 38.

This genus has some affinity to that of *Spondylus*, in which it was, for the most part, included, until separated by Lamarck, but it will at once be distinguished by its being destitute of ears, and in never having the recurved teeth of that genus, nor are the valves separated by an external area. The teeth of this genus are so fitted into their receiving pits that they cannot be separated without injuring the shells; nor will they even admit of the valves being opened wide. The shells of this genus inhabit the seas of tropical and intertropical regions.

Some Fossil species occur in the Lias, the Blue Marls of France, in the Sussex Chalk, and in the Oolitic group of rocks.

Genus.—PLAGIOSTOMA.—*Lluyd.*

Generic Character.— Shell inequilateral, subequivalve, oblique and provided with small ears, mostly higher than long; generally covered with grooves or striæ diverging from the umbones, and passing to the ventral margin; base of the hinge transverse, straight, and destitute of teeth; umbones remote; depression for the ligament, either straight or slightly angular.

Plagiostoma punctata. Plate VII. fig. 39.

The Plagiostomata seem to have been attached by a byssus in their living condition, there being a passage through the anterior part of the shell, which in most of the species is rather open.

The shells of this genus are known only in a fossil state, and most important in a geological point of view, as different species characterise the various strata of limestone, from the carboniferous limestone up to the chalk. The Oolitic beds which intervene betwixt these abound with Plagiostomæ. *P. giganteum* is abundant in the Lias, and the *P. spinosum* is met with in great profusion in the upper chalk.

Genus.—DIANCHORA.—*Sowerby.*

Generic Character.— Shell inequivalve, subtriangular, oblique, adherent; attached valve provided with an angular hiatus, instead of an umbo; the other valve auriculated, and with an obtuse umbo; hinge destitute of teeth.

Dianchora striata. Plate VII. fig. 40.

The Dianchoræ strongly resemble the Plagiostomata, but differ in being always attached, and in being provided with an opening instead of an umbo in the attached valve. The genus is known only in a fossil state, and occurs in the Greensand.

Genus.—PECTEN.—*Bruguière.*

Generic Character.—Shell inequivalve, the under valve generally more convex than the upper, subequilateral, with many grooves or ribs radiating from the umbones to the margins; provided with two ears, which are usually unequal in size; close below one of them in the upper valve is a small notch for the passage of a byssus; muscular impression large, placed somewhat to one side; pallial impression destitute of a sinus; hinge linear, without teeth; ligament consisting of three portions, of which the two lateral parts are elongated, and follow the hinge line, the third portion thick, triangular, and fitted into a central, triangular, shallow pit, within the hinge.

Pecten cornea. Plate VII. fig. 44.

This genus, consisting of numerous species of marine shells, may be separated into the following sections:—

Section 1. Both valves somewhat convex, and not uniting all round as in *Pecten plueronectus.*

Section 2. One valve flat, the other deep and convex, as in *P. Jacobæus.*

Section 3. Both valves convex, equal in size or nearly so, as seen in *P. turgidus.*

Section 4. Both valves convex, but unequal in size, as in *P. bifrons.*

The Pectens inhabit the seas of almost all countries, and are remarkable for the beauty and diversity of their colours and markings; the valves, in most instances, being of different shades and hues.

They abound in a fossil state from the Crag to the Oolitic series of strata.

Genus.—HINNITES.—*Defrance.*

Generic Character.—Shell inequivalve, subequilateral, more or less ovate, thick and strong, covered externally with somewhat irregular, squamose, or radiating ribs; valves eared with a deep and elongated area for the ligament or cartilage, which is wholly internal; a large, ovate impression, which is the seat of the adductor muscle, the mantle impression entire.

Hinnites cortesyi. Plate VII. fig. 45.

Found in the Coral Crag, Ramshot. No recent species are known, and is only met with in a fossil state, in the tertiary formations.

Sub-genus.—LIMATULA.—*S. Wood.*

Generic Character. —Shell longitudinal, equivalve, equilateral; subauriculated; umbones rather large and prominent; ligamental area broad, with a triangular pit for the reception of the cartilage; sides of the valves close.

Limatula ovata.—Wood, *Mag. Nat. Hist.*, 1839, p. 235, Pl. III. fig. 5.

Genus.—LIMA.—*Bruguière.*

Generic Character.—Shell longitudinal, equivalve, inequilateral; sides somewhat thickened, and gaping; umbones divergent, their internal facets inclined outwards; hinge pro-

vided with two lateral teeth, one on each side in both valves, which become nearly obsolete in adult shells; area between the beaks, to which the ligament is attached, is divided; tripartite; the middle or hinge pit is rounded above, and contains the chief portion of the ligament, the remaining portions are attached to the somewhat elongated linear divisions; muscular impression lateral, suborbicular, from the inner margin of which the muscular impression of the mantle emanates, and traversing the other side of the valves in a circuitous form, appears to terminate near the beak; external surface covered with a very thin epidermis.

Lima gibbosa. Plate VII. fig. 42.

The Limæ are marine shells and inhabit the seas of almost all countries. They may be distinguished from the *Ostrea* by their regularity of form, and by never being attached externally. Their oblique form separate them from Pecten. The Limæ are supposed to be attached to other bodies by a byssus.

The shells of this genus abound in a fossil state; they are met with in the inferior Oolite, the Calcaire-grossier of France, in the same strata of Italy, and the London Clay of England. They have not, however, been observed in any of the strata below the Lias.

GRAND DIVISION III.

Shells with an elongated marginal ligament.

TRIBE I.—MALLACEA.

Shells foliaceous, more or less inequivalve, with the ligament marginal, partly linear, and either simple or interrupted by crenulations.

Genus.—Avicula.—*Lamarck.*

Generic Character.—Inequilateral, inequivalve, foliaceous, subquadrate and oblique, pearlaceous within; hinge rectilinear, and produced on each side into straight auriform appendages, with a small indistinct tooth in both valves, an elongated marginal ligamentiferous area, widened near its centre.

Avicula echinata. Plate VII. fig. 50. Found in the Cornbrash Limestone of Wiltshire and Dorsetshire.

Sowerby has united this genus with *Meleagrina*, and remarks that the general form of these shells is somewhat square, with their superior angles rounded. The Meleagrinæ approach nearer the circular form than the Aviculæ, which is a little more transverse. In the latter genus, the two valves are rather more conspicuously unequal than in *Meleagrina*, which is distinctly marked by their pearlaceous interior. The line of the hinge in Aviculæ is transverse and straight, but in some species its extremities are very short as in Meleagrina, but extremely variable in length, and sometimes excessively prolonged. The left hand valve is contracted and notched at the posterior side, near the base, which is less observable in the right hand valve; this is destined for the passage of the byssus. Each valve is generally provided with a single small tooth, placed immediately within the beaks; and is frequently met with in the Meleagrinæ, contrary to the assertion of Lamarck. The area of the ligament is marginal, linear, narrow, and dilated in the centre; which is very conspicuous in old shells, forming an obliquely triangular pit, emanating from below the beaks, and increasing gradually in width towards the centre of the valves. This is common to both *Avicula* and *Meleagrina*. The external rows of imbricated scales are also common to both genera; the muscular impression large, suborbicular, and in both nearly central, with a row of minute ones running from the inner edge to the umbo.

The shells of this genus are oceanic, principally inhabiting the seas of tropical climates; a few species are found in Europe, and two are known to exist in the British seas.

Fossil species occur in the Supercretaceous rocks in Dax and Bordeaux, also in the Cretaceous series, and are rather plentiful in the Oolitic group.

Genus.—Monotis.—*Brown.*

Generic Character.—Shell subequivalve, unequilateral, subauriculate, depressed, closed, auriculated behind, subrotund before; ear continuous; umbones depressed submediate; margin of the hinge linear, callous, and destitute of teeth; canal bending downwards in an outward direction beneath the umbones; closed on the right valve with an entering fold.

The shells of this genus have a deep angular byssal notch, a subtriangular cartilage pit, and a single subcentral muscular impression.

Monotis speluncaria.—King, *Per. Foss.*—A cast of the under valve, exhibiting impressions of the abductor muscle *a*, pallial line *b*, and pedal muscle *c*.

Found in the Permian series, Humbleton Hill.

Genus.—Pterinea.—*Goldfuss.*

Generic Character.—Shell equivalve, inequilateral, both sides furnished with lateral auricles; the anterior one short; the posterior distinctly defined; hinge area broad and lengthened, its superior margin straight, and the surface generally with a series of parallel lines; ligament internal; hinge with several oblique cardinal teeth, situate below the beaks, and with one or more lateral, very oblique, remote teeth, sloping considerably downwards from the umbones to the anterior side, with one large muscular impression in each valve.

Pterinea ventricosa. Plate VII. fig. 21.

The shells of this genus may easily be mistaken for those of avicula, when the inside of the valves are hidden from view.

Genus.—Gérvillia.—*Defrance.*

Generic Character.—Shell oblong, nearly equivalve, greatly inequilateral and oblique; hinge line rather long, linear and nearly straight, with numerous irregular somewhat transverse small pits, and teeth situate below the dorsal edge.

Gervillia aviculoides. Plate VII. figs. 46, 48. Found in the Shanklin sand, Shotover Hill, Oxford, and in the Greensand near Lyme Regis.

It is not known whether this shell is furnished with a byssus, and the ligament cannot be described. It resembles an Avicula in general form, and the hinge approaches to that of a Perna.

Known only in a fossil state; and from the shells with which it is found associated, is supposed to be a marine species. They are met with in all the strata from the Lias to the Baculite Limestone.

Genus.—Crenatula.—*Lamarck.*

Generic Character.—Shell subequivalve, flattened, somewhat distorted and lamellar; hinge lateral, linear, marginal, and internally crenulated; the crenulæ formed in a continuous series along the hinge, each of them presenting a small rounded callosity, and excavated for the reception of part of the ligament; muscular impressions almost obsolete, of an oblong form, and situate near the anterior margin of the pearlaceous substance.

Crenatula ventricosa. Plate VII. fig. 49.

The greater portion of the shell of the Crenatulæ, consists of a foliaceous substance, composed of perpendicular fibres, like the Pernæ, Ostræa, &c. They are distinguished from the Pernæ, by being destitute of a passage for a byssus; and the hinge of the latter genus has a series of straight ligamentary grooves placed across it. The Crenatulæ are obliquely elongated shells, while the Pernæ are rather transverse.

They occur but rarely in a fossil condition, and chiefly in the Oolitic group of rocks.

Genus.—Catillus.—*Brongniart.*

Generic Character.—Shell thick, inequivalve, subequilateral; triangular, deep, with incurved umbones; hinge consisting of a series of transverse grooves.

Catillus Lamarckii. Plate VII. fig. 47. *C. sulcatus.* Plate VII. fig. 20. The first is found in the chalk of Sussex, and the latter in the chalk marl.

Section. 1. Beaks short; valves nearly equal.

Section. 2. Beaks elongated; valves unequal.

This genus consists entirely of fossil species, which are chiefly found in the chalk; a few shells have, however, been found agreeing with the Catillæ in the Todmorden shales, which are referred to this genus.

Genus.—Perna.—*Bruguière.*

Generic Character.—Shell subequivalve, flattened, and somewhat irregular, a little distorted, thickish, and externally lamellar; the laminæ composed of minute perpendicular fibres; beaks small, nearly equal, and situate at the posterior extremity of the hinge margin; hinge linear, marginal, with numerous

transverse, parallel, opposite grooves, which, together with flattened ridges between them, are destined for the reception of the ligament; the anterior extremity of the hinge is narrower than its posterior termination; situate immediately under the extremity of the hinge margin is a posterior sinus, for the passage of the byssus; with a parietal callosity, which is more distinct in the right hand valve than in the opposite; the interior pearlaceous substance of the shell is spread out almost in the same form as the exterior, fibrous, and more extended portion; one distinct, somewhat oblique and irregular muscular impression, and a series of small dots, are placed at the posterior side, near the sinus for the byssus, which answer as points of attachment for a part of the mantle.

Perno maxillata. Plate VIII. fig. 1.

The elevations between the sulci do not fit into the grooves of the opposite valve, when the shell is closed, in the manner as cardinal teeth, but rest against the corresponding ones in the opposite valve.

The front extremity is often protruded in the form of a pointed lobe, but this is not a constant generic character.

The shells of this genus may be confounded with those of *Crenatula*, but that genus is destitute of the sinus through which the byssus passes, and its hinge is lateral. The parallel grooves in the Pernæ contain the *principal* portion of the ligament, whereas this portion is situate in the crenulations of the Crenatulæ; which latter genus consists of much more fragile shells than those of *Perna*. In the Crenatulæ the pearlaceous interior occupies a much smaller portion of the shell, seldom exceeding more than half the dimensions of the valves, extending along the hinge margin, and forming an oblique parallel line from the beak to the extreme point of the valve.

The Pernæ inhabit the ocean, and are found only in the seas of New Holland and India.

Shells of this genus are also known in a fossil state, and are met with in the Calcaire-grossier, the Clunch Clay, the London Clay, and in the Oolitic group of rocks.

Genus.—Pluvinites.—*Defrance.*

Generic Character.—Shell inequivalve, very inequilateral; compressed, and thin; anterior side gaping a little; one valve much flattened, the other a little convex; hinge linear, short, situate immediately behind the umbones, and divided by perpendicular grooves; each valve furnished with two small muscular impressions, one of which is very minute, and placed close below the hinge, the larger one lower down, and almost central; ligament supposed to be internal.

Pluvinites Adansoni. Plate VIII. figs. 5, 6.

This shell, the only one of the genus, is closely allied to both Crenatula and Catillus, and is known only in a fossil state. It is found in a stratum of Baculite limestone, near Fresville, at Volognes, Normandy.

TRIBE II.—MYTILACEA.

Hinge, with the ligament subinterior, marginal, linear, very entire, occupying a great portion of the anterior border; shell rather foliaceous.

Genus.—Pinna.—*Linnæus.*

Generic Character.—Shell equivalve, longitudinal, oblique, wedge-shaped; beaks forming an elongated point; posterior side generally truncated, and always gaping; the anterior margin nearly a straight line, and a little open in the centre for the passage of the byssus; hinge without teeth; margin greatly lengthened and linear; ligament partly internal, and continuing along the whole dorsal margin; two muscular impressions in each valve, the posterior one very large, almost central, the anterior one terminal, and sometimes double; muscular impressions of the mantle destitute of a sinus.

Pinna lanceolata. Plate VIII. fig. 3. *P. margaritacea.* Fig. 2.

The shells of this genus cannot be mistaken, their characters being so dissimilar to all others. There are some of the more produced Mytili, which bear a distant resemblance to them, but these are at once distinguished by their basal termination being closed. Some of the Pinnæ grow to a large size, exceeding two feet in length. They are extremely brittle, from their fibres being perpendicular, and arranged alongside of each other, and but slightly attached. A very thin pearlaceous substance is spread over the inside, but hardly extends beyond the muscular impression of the mantle, and merely covering that portion of the shell occupied by the animal.

The Pinnæ are marine shells, and are found in most seas. Three species inhabit the British coasts.

Several fossil species are met with in the tertiary and secondary strata of marine origin. The London Clay contains one species, and one also occurs in the Calcaire-grossier of France.

Lamarck applies the specific term *subquadrivalvus* to some of the Pinnæ, and *tetragona* to another, which seems to have been suggested to him by the circumstance of the pearlaceous substance of their interior being longitudinally divided, taking its rise at the internal anterior point, and continuing somewhat more than half-way towards the centre of the posterior side; an external organ corresponding to this is frequently observable; and such shells easily break in the direction of this line.

Genus.—Dreissina.—*Van Beneden.*

Generic Character.— Shell equivalve, very inequilateral, subtriangular, boat-shaped, or mytiliform; valves carinated; ligament linear, internal; hinge composed of an imperfectly developed cardinal tooth, in the right valve, with a corresponding socket for its reception in the left; three muscular impressions, the palial impression obscure; beaks terminal furnished with a transverse partition; surface covered with an epidermis, in the recent state.

Dressina polymorpha. Brown's Fossil Conch., Pl. LXXI. figs. 3, 4. Found in the lower fresh water formations, Hordwell.

Genus.—Mytilus.—*Linnæus.*

Generic Character.—Shell equivalve, regular, longitudinal, somewhat wedge-shaped, with the beaks terminating in a pointed summit; posterior side rounded, and closed; base forming a continuous line with the interior margin in a direction oblique to the hinge line; anterior margin gaping slightly in the centre for the passage of the byssus; hinge destitute of teeth; ligament marginal, linear, greatly elongated, and subinternal; outside covered with a strong horny epidermis; two muscular impressions, the posterior one large and irregular, the anterior very small and terminal; muscular impressions of the mantle irregular; destitute of a sinus.

Mytilus antiquorum. Plate VIII. fig. 8.

The shells of the genera, *Modiola* and *Lithodomus*, may be mistaken for Mytili; but will be at once recognised by their umbones not being terminal as in the Mytili.

The shells of this genus are all marine. They abound on all rocky shores, and in the estuaries of rivers.

Some of the species are provided with minute denticles within the point close below the beaks, which, however have no connection with, or influence upon, the hinge.

A few fossil species of the genus *Mytilus* are known, they are met with in the Crag, and occur in the strata both above and below the Chalk.

Genus.—Edmondia.—*De Koninck.*

Generic Character.—Shell tumid, equivalve, inequilateral, transversely suboval, or rounded, striated transversely, the lunule gaping; hinge destitute of teeth; hinge with a small transverse plate, internal greatly strengthened by an internal ligament.

Edmondia Murchisoniana. King, *Permian Fossils*, Pl. XIV. figs. 14, 17.

Genus.—Modiola.—*Lamarck.*

Generic Character.—Shell subtransverse, equivalve, regular, oblique; form oblong, somewhat wedge-shaped, and greatly inequilateral; anterior side very small and obtuse; posterior side rounded and closed; anterior margin slightly gaping for the passage of the byssus, and forming with the base a line oblique to the dorsal one; beaks nearly lateral; outside covered with a strong horny epidermis; hinge without teeth; ligament elongated and subexternal; two muscular impressions, the posterior one large, sublateral, elongated, and irregular, the anterior one small and terminal; the pallial impression irregular, and destitute of a sinus.

Modiola cuneata. Plate VIII. fig. 12.

The Modiolæ are distinguished from the Mytili, by their beaks not being terminal, but placed a little within the posterior or smaller side of the valves.

The shells of this genus inhabit the ocean, and four species are found in the British seas. They occur fossil in the Oolitic series, and also in other beds both above and below the Chalk.

Genus.—Crenella.—*Brown.*

Generic Character.—Shell equivalve, very inequilateral, tumid, or compressed; surface covered with an epidermis, and either entirely or partially ornamented by striæ, radiating usually in two diverging fasciculi from the beak; hinge margin destitute of teeth, but generally crenulated; ligament internal and linear, two unequal muscular impressions; the pallial impression obscure.

Crenella marmorata. Plate VIII. fig. 4.

From the Coral Crag, Sutton, and the Red Crag, Walton Naze.

Genus.—Lithodomus.—*Cuvier.*

Generic Character.—Shell transverse, equivalve, regular, elongated, and of a cylindrical form when the valves are shut; rounded at both extremities; anterior side very short; external surface covered with a strong horny epidermis; beaks placed anteriorly, and hardly prominent; hinge destitute of teeth, linear, the hinge line forming a greater or less obtuse angle with the posterior margin; ligament linear and internal, with a small portion exposed externally; two indistinct muscular impressions, the anterior one very small, the posterior one large and oblong.

Lithodomus antiquus. Plate VIII. fig. 11.

The Lithodomi are all sea shells, inhabiting the West Indies, Mediterranean, and all coral rocks.

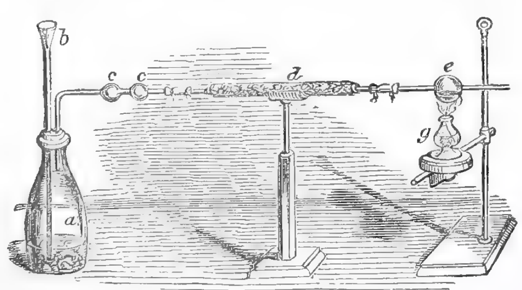
Fossil shells of this genus are plentiful, especially in the Great Oolite, Pisolite and Coral Rag; they also occur in the marine Tertiary beds, and have by several authors been mistaken for Fistulanæ, owing to the decomposition of the *Madrepora* which they inhabited, surrounding them, and producing the appearance of their being encased in an echinated sheath.

INORGANIC CHEMISTRY.

CHAPTER X.

COBALT.

Cobalt is best precipitated from its solutions by potash. Heat is applied, and the filter washed with hot water. As, however, the oxide during ignition passes partially into a higher state of oxidation, it is necessary to convert it into metal by



hydrogen gas. The flask, *a*, in the figure, contains sulphuric acid and water, with fragments of zinc. Acid may be added through the funnel, *b*; the gas escapes through the tube, *c*, and depositing part of its moisture in the bulbs, is perfectly dried in *d*, a wide tube filled with chloride of calcium; *e* is the reduction-tube, containing the oxide in its bulb. As soon as the apparatus is filled with hydrogen, heat is applied by means of the spirit-lamp, *g*. The reduction-tube is first weighed empty, and re-weighed after introduction of the oxide. A strong red heat is necessary. The water, which condenses in drops at the outer end of the reduction-tube, is chased away with the flame of a lamp. When the production of water ceases the spirit-lamp is extinguished, but the current of hydrogen is kept up while the tube is cooling. When cool, the reduction-tube is weighed. The weight shows the amount of metal present in the sample of oxide, whilst the loss shows the proportion of oxygen with which it was combined. (1.) If ammonia or ammoniacal salts be present, the cobalt must be precipitated from a neutral or alcaline solution by hydrosulphate of ammonia. The precipitated sulphuret is washed with water containing a little hydrosulphate of ammonia, removed as completely as possible while still moist from the filter, and put into a glass. The filter is then ignited in a porcelain capsule, and its ashes also placed in the glass. The whole is now dissolved in warm nitro-muriatic acid, diluted with water, filtered, and precipitated with potash. The precipitate is then washed, ignited, and reduced as above.

The peroxide of cobalt is estimated by reduction with hydrogen gas at a red heat.

From manganese, zinc (and nickel), cobalt is separated as follows:—The solution is neutralised by carbonate of soda, if acid, and treated with cyanide of potassium in excess. Carbonate of soda is then added, and the liquid boiled, when manganese is precipitated. The cyanides in the filtered liquor are now destroyed by digestion with muriatic acid, when the further addition of carbonate of soda precipitates the cobalt. Zinc (and nickel), if present, remain in solution.

From peroxide of iron, cobalt is separated by dissolving the oxides in sulphuric or muriatic acid, or in a mixture of both. Nitric is to be avoided. Caustic potash is now added, continually stirring until the mixture has only a very feeble acid reaction. In this manner the iron is thrown down as a basic salt. Water is now added, and the solution and precipitate boiled for a short time. Any remaining trace of iron is thus precipitated. The solution is filtered while hot, and the filter washed with boiling water. From the filtrate the cobalt is precipitated in the ordinary manner. Nitric acid should not be present.

From alumina cobalt is separated by caustic potash, which holds the earth in solution.

From magnesia cobalt (and nickel) may be separated as follows:—The mixed solution is treated with caustic potash and hypochlorite of potash. The precipitate, after washing, is digested in a solution of chloride of mercury, at about 90° F. The filtrate and washings are evaporated to dryness, heated to expel mercury, drenched with pure nitric acid, evaporated down in the water-bath, ignited, and weighed. The oxide of cobalt is ignited to expel mercury, and nickel, if present, separated from it as below.

From lime cobalt is separated by oxalate of ammonia; or, preferably, by hydrosulphate of ammonia, which precipitates the cobalt. The liquid is allowed to settle in a corked flask, and then rapidly filtered to avoid contact of air. From the filtrate lime is precipitated, after destroying the hydrosulphate with muriatic acid.

From strontia cobalt is separated as from lime, or by means of sulphuric acid.

From baryta cobalt is separated by sulphuric acid. Cobalt may also be freed from lime, strontia, and baryta, by adding cyanide of potassium in excess to the mixture, which should be acid, heating, and adding carbonate of potash, which throws down the earths.

From the alcalies cobalt is separated by hydrosulphate of ammonia.

NICKEL.

Oxide of nickel is precipitated by potash. The liquid is heated, and the precipitate washed with hot water. The presence of ammoniacal salts is unimportant. If it is required to throw down this metal as sulphuret, the solution is copiously diluted, and treated with hydrosulphate of ammonia, avoiding excess. The vessel is covered up and set in a warm place until the clear liquid is no longer brown, when the precipitate is filtered, and washed with water containing a trace of hydro-

sulphate of ammonia. The sulphuret is treated like that of cobalt. Peroxide of nickel may be converted into protoxide by ignition.

Cobalt and nickel are separated by saturating the dilute solution with chlorine gas, and digesting in this solution, for 24 hours, an excess of carbonate of baryta. The nickel remains in solution, whilst the cobalt is precipitated as peroxide, which is then easily separated from the baryta.

Liebig dissolves the mixed oxides in hydroganic acid and potash, and boils for half an hour in a flask. Digestion with oxide of mercury precipitates the nickel.

From zinc nickel is separated by converting both into acetates, adding free acetic acid, and precipitating the zinc by sulphuretted hydrogen.

From iron nickel is separated by dissolving the oxides in muriatic acid, and adding carbonate of baryta in excess. Iron falls as a light brown powder. The mixture of iron and baryta is dissolved in muriatic acid, filtered, and the baryta removed by sulphuric acid.

From manganese nickel is separated in the same manner as zinc.

From alumina and glucina nickel is removed by the use of potash, which dissolves the earths.

From magnesia nickel is withdrawn by adding muriate of ammonia, free ammonia, and hydrosulphate of ammonia, avoiding excess of the last re-agent. The precautions usual on precipitating nickel as a sulphuret are observed.

From lime nickel is separated by adding oxalate of ammonia to the ammoniacal liquid, and filtering rapidly.

From lime, strontia, and baryta, nickel is separated by adding cyanide of potassium in excess, and afterwards carbonate of potash. Heat is next applied, and the insoluble earths removed by filtration. The filtrate is boiled with hydrochloric acid to destroy the cyanides, and oxide of nickel is then thrown down by potash.

Nickel is separated from the alcalies as from magnesia; or the compound is dried, and heated in a current of hydrogen gas. The alcalies are removed from the reduced metal by water.

Cadmium is thrown down by carbonate of potash. It is dried, ignited, and weighed, as brown oxide. The filter should be burnt separately.

From all the foregoing substances cadmium may be separated by passing a current of sulphuretted hydrogen through the dilute acid solution. The precipitate is dissolved and re-precipitated by carbonate of potash.

LEAD.

Lead is precipitated by oxalate of ammonia from a neutral solution. The precipitate, on ignition, is converted into protoxide. The filter should be burnt separately, and its ashes added. The ignition should be performed in a thin porcelain crucible. Lead may also be thrown down by carbonate of ammonia. The liquid is heated, and a little caustic ammonia added. The carbonate, on ignition, is converted into protoxide. Lead may also be estimated as sulphate. The acid is diluted and added in excess. The precipitate is washed with dilute alcohol, or very dilute sulphuric acid.

The higher oxides of lead are reduced to protoxide by ignition.

From cadmium lead is separated by adding sulphuric acid, evaporating to dryness, heating the residue to expel excess of acid, adding water, which dissolves sulphate of cadmium, slightly washing the precipitate of lead, drying, and igniting. Or they may be separated by adding cyanide of potassium in excess, when lead is precipitated, whilst cadmium remains in solution. The lead is dissolved in nitric acid, and re-precipitated as oxalate.

From the other bodies already mentioned lead is separated by sulphuretted hydrogen from a dilute solution, acidulated with nitric acid. The precipitate is dried, put in a capsule along with the filter (which should be small), and gradually drenched with the strongest nitric acid. When the action is over, a very little sulphuric acid is added, the mass heated to expel free acid, ignited, and weighed. Or muriatic acid may be first added until HS no longer escapes, next nitric acid, and, after evaporation to dryness, sulphuric acid. Any excess of the latter is expelled by a moderate heat before ignition.

BISMUTH.

Oxide of bismuth is precipitated by carbonate of ammonia. Whether the solution was previously clear or turbid is immaterial. The whole is left to settle for some hours in a warm place before filtration. The filter is burnt separately. The solution must contain no hydrochloric acid. Otherwise, we precipitate with hydrosulphate of ammonia, wash, re-dissolve in nitric acid at a moderate heat, filter, and precipitate the clear liquid with carbonate of ammonia. Metallic alloys containing bismuth are dissolved in nitric acid.

From lead bismuth is separated by adding sulphuric acid to the mixed solution, expelling the free acid by heat, adding water, and filtering. The precipitated sulphate of lead is washed in water containing a little sulphuric acid.

Ullgren precipitates both metals by carbonate of ammonia, dissolves in acetic acid, and places a strip of pure lead of known weight in the solution. The flask is then corked up, and allowed to stand for several hours. When all the bismuth has been precipitated, the lead is removed, washed, dried, and weighed. The bismuth is thrown on a filter, washed with water which has been freed from atmospheric air by boiling, and allowed to cool in a stoppered bottle. The metal is then dissolved in nitric acid, and estimated as usual.

From cadmium bismuth is separated by dissolving both in an acid, and adding paraphosphoric acid and excess of ammonia. Bismuth is precipitated as a phosphate, and is filtered off.

From the foregoing bodies bismuth is separated by sulphuretted hydrogen. Acetic acid is added, and the solution largely diluted with water.

URANIUM.

Peroxide of uranium is thrown down by ammonia. The precipitate is washed with muriate of ammonia, dried, and ignited, during which process it is converted into the black oxide, $U^4 O^5$, if the temperature be high, and into the olive oxide, $U^3 O^4$, if a dull red heat be employed with access of air. The crucible is removed from the lamp to a piece of cold metal that it may cool rapidly. Protoxide of uranium, before precipitation, is peroxidized by nitric acid.

From bismuth, lead, and cadmium, uranium is separated by treating the acid solution with HS. The three former are precipitated, whilst uranium remains in solution. The filtrate is heated to expel HS, and the uranium determined as usual.

From nickel, cobalt, zinc, and manganese, uranium is removed by adding nitric acid, if the protoxide be present, diluting the solution, which should not be very acid, and adding carbonate of baryta in excess. The mixture is left to stand for three days at common temperatures, and frequently stirred. Uranium is thrown down, whilst the other oxides remain in solution. The mixed precipitate is dissolved in muriatic acid, the baryta removed by sulphuric acid, and the uranium determined as usual. Ebelmen separates zinc, cobalt, and nickel from uranium by diluting the solution, and adding bicarbonate of potash in slight excess. Uranium dissolves as a double carbonate, whilst the other metals are precipitated.

From iron uranium is separated by boiling the solution after the addition of sulphate of ammonia. Uranium falls as a yellow precipitate, while iron remains in solution. Or, carbonate of ammonia is added in excess to the mixed solution, largely diluted. Iron falls as peroxide, while uranium remains in solution.

Manganese and magnesia are separated from uranium in the same manner as from cobalt, nickel, and zinc.

Alumina is separated from uranium as from iron. Lime and strontia are removed by adding sulphuric acid and alcohol. The mixed sulphates of lime and strontia precipitated are washed with alcohol; sulphate of uranium remains in solution.

From baryta uranium is separated by sulphuric acid.

From the alcalies uranium is separated by ammonia in excess, the precipitate being afterwards washed with muriate of ammonia.

COPPER.

Copper is precipitated by potash. The liquid should be hot, and moderately dilute. The whole is boiled until the precipitate appears a blackish brown. Hot water is employed for washing. The crucible is weighed as soon as cool, and must be kept well closed to prevent absorption of moisture. If any portion of the precipitate adheres to the capsule, it is dissolved off with an acid, diluted, re-precipitated with potash, and added to the rest.

From bismuth copper is separated by carbonate of ammonia in excess; copper is dissolved and bismuth precipitated. The whole is allowed to settle for some time in a warm place. The precipitate is washed, first with carbonate of ammonia and then with water.

From lead copper is separated by dissolving in nitric acid, adding sulphuric acid, evaporating to dryness, and, at the end, applying heat enough to expel any excess of acid. The mass is then drenched with water, which dissolves sulphate of copper, leaving sulphate of lead. The latter is filtered, dried, and slightly ignited. After the copper has been removed from the filtrate by potash in the usual manner, the liquid is neutralized with nitric acid, and any residual trace of lead precipitated by oxalate of ammonia. Or, a current of sulphuretted hydrogen may be passed through the solution, and the precipitate treated with cyanide of potassium. Copper dissolves, while lead remains insoluble.

From cadmium copper is separated by adding cyanide of potassium in excess. HS is then passed through the solution; more cyanide of potassium is added, after heat to expel free HS, until all cadmium is thrown down and all copper dissolved.

Copper may be separated from zinc and nickel by adding hyposulphate of soda to the boiling solution, which has been acidulated with sulphuric acid. A sulphuret of copper is formed which does not carry down with it nickel or zinc.

From the same metals, as well as from manganese, iron, and cobalt, copper may be separated by saturating with sulphurous acid and adding hydriodic acid. Copper is precipitated as iodide.

From uranium, the earths, and alcalies, copper is precipitated as sulphuret by HS from an acid solution. The precipitate is filtered rapidly, and washed with water containing HS. The sulphuret is collected in a beaker, the ashes of the filter added, and the whole drenched with nitro-hydrochloric acid. From the filtrate copper is precipitated as oxide by potash.

SILVER.

Silver is thrown down from acid solutions by hydrochloric acid. If ammonia or the alcalies be largely present, the filtrate is evaporated almost to dryness, and the residue treated with nitric acid. On the application of heat, the alcaline chlorides are converted into nitrates, and deposit any trace of silver they may have dissolved. This is then filtered off and added to the main portion. The precipitate is heated well, allowed to stand in a dark place for a day, thrown on a small filter, and washed, at first with water containing a trace of muriatic acid, and then with pure water. It is then dried, and ignited in a porcelain crucible. The filter is burnt separately on a crucible cover.

From all the metals hitherto mentioned silver is separated by hydrochloric acid. Lead is, indeed, precipitated by hydrochloric acid, but may be removed by long washing.

MERCURY.

Mercury is reduced from its solutions to the metallic state by protochloride of tin. Nitric acid must not be present. If the substance is insoluble, it is boiled in a flask with hydrochloric acid and protochloride of tin for a few minutes. The flask is then corked, and allowed to cool. The liquid is decanted off, and distilled water added until all foreign matter is removed. The mercury is then poured into a porcelain capsule, and dried by means of blotting paper, and exposure to the air without heat. If the mercury will not form large globules, the clear liquid is poured off, and muriatic acid boiled upon the sediment. If a mercurial film floats on the surface, it is made to subside by shaking. All the washing liquors are put aside in a glass to settle, and any mercury which subsides is added to the former portion. The vessels used should be perfectly free from all traces of grease. If nitric acid be present, it should be destroyed by boiling with hydrochloric acid before the salt of tin is added.

Mercury may also be determined as subchloride. The mercury, if combined with a metal, is dissolved in aqua-regia. If nitric acid be present, it is destroyed by hydrochloric acid. Potash is then added so as to leave the liquid feebly acid. Formiate of soda is added, and the whole left for several days at about 160° F. The mercury is then deposited as subchloride (calomel). The precipitate is collected on a weighed filter, the filtrate mixed with an additional quantity of formiate and allowed to stand for a day, and any further precipitate obtained is added to the former. The whole is now dried at a gentle heat until its weight becomes constant.

From silver, mercury is separated by hydrochloric acid; from the filtrate mercury is thrown down as above. If silver is combined with a subsalt of mercury, the latter is peroxidized by nitric acid. From copper, mercury is separated by neutralizing the acid liquid with carbonate of soda, and adding cyanide of potassium in excess. From this solution, mercury alone is precipitated by the hydrosulphate of ammonia.

From lead, mercury is separated by drenching with hydrochloric acid, and heating the mixture. Alcohol, poured on the dry residue, dissolves out the perchloride of mercury, leaving chloride of lead, which is thrown on a balanced filter, washed with alcohol, dried, and weighed. From the filter, alcohol is driven off at a low heat, and the mercury determined as above. Lead may also be removed by sulphuric acid in excess.

From bismuth and cadmium, mercury is separated by cyanide of potassium in excess. The whole is boiled with dilute nitric acid. Cyanide of mercury is unattacked, whilst the two others are converted into nitrates.

From the remaining substances, previously mentioned, mercury is separated by HS. The sulphuret is filtered and washed, put along with the filter in a large stoppered flask, drenched with hydrochloric acid, and chlorine gas slowly passed through the solution. The mercury is converted into chloride, which remains in solution, and after the expulsion of free chlorine, is determined as above. From all non-volatile oxides, mercury is expelled by heat.

If the two oxides of mercury exist together, their amount may be determined by diluting with a large excess of water, and adding muriatic acid, which throws down mercury as subchloride. The liquid is allowed to stand in a cold place. The precipitate is thrown on a balanced filter, and dried at a low heat till its weight is constant. From its weight, the amount of suboxide is calculated. The amount of protoxide is then determined in the usual manner from the filtered liquid. If the substance is insoluble in water, cold dilute muriatic acid is used as a solvent. If nitric acid be present, the compound is first dissolved in dilute nitric acid before the muriatic is added.

RHODIUM.

Rhodium is determined by adding carbonate of soda in excess, evaporating to dryness, igniting, and extracting the residue with water. The peroxide of rhodium is well washed, reduced by hydrogen gas at a low temperature, and weighed as metal.

From copper, rhodium is separated by putting the liquor in a stoppered flask, and saturating it with HS. The flask is then stoppered, and allowed to stand in a warm place for a day. Sulphuret of copper and a portion of rhodic sulphuret are precipitated. More of the latter is obtained when the liquid is heated and concentrated. The moist mass is roasted in a platinum crucible as long as sulphurous acid is developed. Strong hydrochloric acid is then poured upon the residue, which dissolves copper, leaving rhodium untouched. Any trace of rhodium in the liquor, filtered from the metallic sulphurets, is obtained by treatment with carbonate of soda.

From iron, rhodium is separated by a current of HS., which throws down most of the rhodium as sulphuret, which is peroxidized by roasting. The filtrate is heated with nitric acid, precipitated with ammonia, washed, ignited, weighed, reduced

in hydrogen gas, and dissolved in hydrochloric acid, heat being applied at the end. A little rhodium remains undissolved, and is peroxidized on ignition in the air. Its weight is deducted from that of the peroxide of iron. To the liquor, from which the iron was precipitated, carbonate of soda is added. It is evaporated to dryness, ignited, extracted with hot water, when peroxide of rhodium remains. All these portions of rhodium are put together and reduced by hydrogen.

From the alkalies, rhodium is separated by igniting a given weight of the mixed chlorides in a current of hydrogen, as long as hydrochloric acid is evolved. The reduction tube is weighed and extracted with water. The reduced rhodium is dried, ignited in a current of hydrogen, and weighed.

PALLADIUM.

Palladium is precipitated from its solutions by cyanide of mercury. The solution, if acid, is neutralized with carbonate of soda. On ignition, metallic palladium remains.

From metals not precipitable by HS, palladium is easily separated by a current of that gas. The sulphuret thus obtained becomes, on roasting, a subsulphate. It is dissolved in hydrochloric acid neutralized with soda, and determined as above.

From copper, palladium is separated by dilution or solution of the metals in nitric acid, adding formiate of soda, and boiling as long as carbonic acid is disengaged. Palladium is reduced as a grey powder, while copper is held in solution.

Palladium is separated from silver by muriatic acid.

IRIDIUM.

To determine iridium, the concentrated solution is mixed with a solution of chloride of ammonium, likewise concentrated, and very strong alcohol added until the mixture contains about 60 per cent. by measure of alcohol. The precipitate is filtered, washed with alcohol, and reduced by heating in a current of hydrogen gas.

From all metals not precipitated by HS, iridium is easily separated by this reagent.

OSMIUM.

Osmium is separated from its solutions by formic acid, which reduces it as a deep blue powder.

From other metals, osmium may be separated as osmic acid, owing to its volatility. From iridium, with which it forms a very intimate compound, it is separated as follows:—The alloy is finely pulverized in a steel mortar, boiled in muriatic acid to remove particles of iron, the solution decanted off, and the residue washed. It is then mixed with about its own weight of fused saltpetre, in a small porcelain retort adapted to a tubulated receiver, from which proceeds a tube leading into a vessel of ammonia. Heat is applied gradually, at first, up to full whiteness. The residue in the retort is treated with cold water, and the solution put in a stoppered flask, and mixed with nitrohydrochloric acid. The clear liquid is distilled in a retort, the joints being well luted, and the receiver carefully cooled. The portion insoluble in water is mixed with nitro-hydrochloric acids, and distilled in another retort. The distillates contain osmium, the residues iridium with a trace of osmium. The residues are filtered, mixed with chloride of potassium, and dried. The mass is well mixed with carbonate of soda and heated in a retort as before, and the volatilized osmium collected. The residue leaves iridium on exhaustion with water. A remaining trace of iridium is removed by heating the mass in hydrogen gas, and afterwards in the air as long as the odour of osmium is perceptible.

PLATINUM.

Platinum is reduced by the addition of formiate of soda. Or the strong acid solution is treated with concentrated chloride of ammonium and alcohol. The precipitate is washed in dilute spirit containing a little sal-ammoniac. On ignition, metallic platinum remains, and may be weighed as such. The salt is placed in the crucible wrapped up in the filter, the cover is put on, and a moderate heat applied. The cover is then partially withdrawn, and the heat increased. The salt may also be heated in a current of hydrogen.

Platinum may be separated in the above-mentioned manner from manganese, iron, cobalt, copper, mercury, and all metals whose chlorides are soluble in dilute alcohol. If traces of other metals are precipitated along with the platinum, they may be removed by digesting the mass after reduction in nitric or in muriatic acid. From those oxides not precipitable by HS, platinum is easily separated by this reagent. The sulphuret is converted by ignition into metallic platinum. From silver, platinum is separated by boiling sulphuric acid, which dissolves the former. Sulphuret of platinum is soluble in hydrosulphate of ammonia, which enables it to be separated from a certain class of metals.

For the analysis of platinum ores and platinum residues, the reader is referred to a subsequent chapter, on mineralogical analysis.

GOLD.

Gold is determined by reduction. Protosulphate of iron is added, which throws down gold as a fine brown powder. Muriatic acid should be added to prevent the deposition of any iron. The solution is allowed to stand in a warm place, the gold thrown on a filter, dried, ignited, and weighed. Nitric acid, if present, must be previously destroyed by heat, and the addition of hydrochloric acid. Oxalic acid likewise precipitates gold on prolonged digestion.

From copper, uranium, bismuth, cadmium, nickel, cobalt, zinc, iron, manganese, the earths and alkalies, gold is separated by adding muriatic acid in slight excess, and then digesting with oxalic acid. From metals not thrown down by HS, gold may be separated by a current of this gas. Sulphuret of gold is further soluble in hydrosulphate of ammonia, by which means it is separated from copper, bismuth, cadmium, and lead. The solution for this purpose is concentrated, and mixed with ammonia and hydrosulphate of ammonia in excess. The whole is allowed to stand for some time in a covered beaker. The residue is thrown upon a filter, and washed with water containing a trace of the hydrosulphate. From the filtrate, the gold is precipitated by the addition of diluted hydrochloric acid. The precipitate is dried, ignited, and weighed.

From platinum and iridium, gold may be separated by dissolving in nitrohydrochloric acid, concentrating the solution, adding alcohol in large excess, and precipitating the platinum by the chloride of potassium or ammonium. Or oxalic acid may be added to the mixed solution, which reduces and precipitates the gold without affecting the platinum.

From silver, gold is separated, when the former does not exceed 15 per cent., by extending it into a thin surface, and dissolving in nitrohydrochloric acid. Gold is dissolved, whilst silver remains as an insoluble chloride. If the silver exceed 80 per cent., the laminated mass is treated with nitric acid, which leaves metallic gold untouched. If the amount of silver be intermediate (above 15 and below 80 per cent.), the alloy is fused with three times its weight of pure lead (obtained by igniting common sugar of lead). The whole is then treated with nitric acid. Lead and silver dissolve, whilst gold remains untouched. Further remarks on the commercial assaying of gold alloys will be given on a future occasion.

TIN.

Tin, in the metallic state, is treated by boiling nitric acid, and determined as insoluble peroxide. If in solution, it is likewise concentrated and boiled with nitric acid until insoluble peroxide is formed. Muriatic acid, if present, must be destroyed by prolonged heat, and the addition of nitric acid in excess. The precipitate is filtered, ignited, and weighed. Tin may also be determined by saturating with ammonia, and adding succinate of ammonia. The precipitate, washed with cold water, is converted on ignition into peroxide of tin. Ignition generally expels the acids present, if a sufficient quantity of nitric acid has been previously applied.

From dilute solutions, tin, whether existing as protoxide or peroxide, may be separated by means of HS. The whole is allowed to digest at a gentle heat, that the precipitate may settle. The sulphuret thus obtained, filtered and dried, is roasted in a platinum crucible at a very gentle heat. When sulphurous acid no longer exhales, the temperature is raised

to redness. The residual peroxide is heated with a fragment of the carbonate of ammonia—a process which must be repeated until the weight becomes constant.

Native peroxide of tin, insoluble in acids, is mixed in fine powder with three times its weight of an alkaline carbonate, and ignited. The peroxide is thus rendered soluble in acids.

From metallic alloys tin is easily separated. The oxides of the metals already mentioned dissolve in nitric acid, whilst peroxide of tin remains insoluble. If bismuth be present, the water used in washing must be acidulated with nitric acid. Tin is thus withdrawn from alloys of silver, copper, bismuth, lead, mercury, cadmium, nickel, cobalt, zinc, iron, and manganese.

From uranium, nickel, cobalt, zinc, iron, manganese, the earths and alkalies, tin is separated by HS, the solution being acidified with hydrochloric acid, in which latter the compound, if solid, should be dissolved. If this is impracticable, sulphuric acid, slightly diluted, may be applied. Should the substance prove insoluble in acids, ignition with an alkaline carbonate is necessary; after which the residue dissolves in hydrochloric acid. From oxides of mercury, silver, copper, bismuth, lead, and cadmium, tin is separated, by adding ammonia and hydrosulphate of ammonia in excess; sulphuret of tin dissolves, while the other sulphurets remain insoluble. If the tin was present as protoxide, powdered sulphur is added to the hydrosulphate, which facilitates the solution. The filtrate is diluted with water, and acidulated with hydrochloric acid, when sulphuret of tin is deposited, The whole is now digested and filtered, and treated as above.

If proto and per salts of tin are jointly present, they may be separated as follows:—The tin solution is poured into a solution of protochloride of mercury (the latter in excess); the whole is heated, and, after standing a considerable time, filtered. The precipitate (subchloride of mercury) is thrown upon a balanced filter, dried at a gentle heat, and weighed. From its amount, the proportion of protoxide, &c., of tin in the original solution may be easily calculated. The whole amount of tin present in the solution is ascertained from another portion, in the usual manner, and by subtracting the first of these results from the second, the quantity of perchloride is determined.

TITANIUM—TITANIC ACID.

Titanic acid is best precipitated by means of ammonia, avoiding excess. The solution, after standing for some time in a warm place, is filtered, the precipitate dried, ignited, and weighed in a well-closed platinum crucible.

Titanic acid, in its insoluble state (rutile, &c.), is cautiously ignited with an excess of an alkaline carbonate. The residue is soluble in cold dilute hydrochloric acid.

From all metals precipitable by HS, titanium is separated by means of this gas, the solution being rendered acid.

From nickel, cobalt, zinc, iron, and manganese, titanic acid is separated by adding tartaric acid and excess of ammonia, which should produce no precipitate. Hydrosulphate of ammonia is then added, which throws down the other metals as sulphurets, whilst titanic acid remains dissolved. The former are filtered off, and determined as above. If the filtrate contain no other fixed matter, it is evaporated to dryness, and the residue ignited in a balanced platinum capsule. The residue of titanic acid is then weighed. If titanic acid is combined with both protoxide and peroxide of iron, two distinct portions must be submitted to analysis. Each is pulverized, dried, weighed, placed in a stoppered flask, and dissolved in concentrated hydrochloric acid. The insoluble residue is impure titanic acid. A solution of soda—chloride of gold—is rapidly added to one portion, the flask stoppered and set in a cool place. The metallic gold precipitated is weighed, and dissolved in weak nitrohydrochloric acid. Impure titanic acid remains, which is filtered off, ignited, weighed, and its weight deducted from the weight of the gold. The residue is equivalent to the amount of protoxide of iron. The flask, with the other portion, is then filled up with a concentrated, recent, and clear solution of HS. Sulphur is deposited in a few days, proportional to the sesquioxide of iron. The whole is filtered as rapidly as possible, air being excluded. The sulphur is washed, dried at a gentle heat, weighed, and burnt. Titanic acid remains, which is weighed and deducted, both from that of the sulphur, and of the body under examination. The filtrate from the sulphur is acidulated with tartaric acid, supersaturated with ammonia, and treated with hydrosulphate of ammonia. The sulphuret of iron thus precipitated, is peroxidized and estimated in the usual manner. The amount of iron thus found must agree with the joint quantity of protoxide and sesquioxide, as deduced from the former operations. The titanic acid is estimated in the ordinary manner in the last filtrate. Titanic acid may also be separated from iron, manganese, zinc, cobalt, nickel, and uranium, by dissolving in hydrochloric acid, saturating with HS, adding ammonia in excess, allowing the precipitate to settle, protected from air, decanting off the clear liquid, and adding aqueous sulphurous acid, until its odour is distinct. Titanic acid remains insoluble, whilst the other metals dissolve as hyposulphites.

The separation of titanic acid from zirconia is still a desideratum.

From ceric and yttric oxides it is separated by prolonged boiling in dilute sulphuric acid, when the titanic acid is precipitated.

From alumina and glucina it is separated in the same manner.

From magnesia it is separated by ammonia, sal-ammoniac having been previously added.

From lime titanic acid is also separated by ammonia, contact with air being avoided, to prevent the precipitation of chalk. Baryta and strontia are withdrawn from titanic acid by means of sulphuric acid.

From the fixed alkalies titanic acid is separated by ammonia.

Native titanates, if not soluble in muriatic acid, may be rendered so by fusion, in the state of fine powder, with an alkaline carbonate.

ANTIMONY.

This metal may be determined as a sulphuret. Its solutions, if containing muriatic acid, must not be concentrated by evaporation, since a portion of antimony escapes as chloride. This loss may be almost entirely prevented by the addition of nitric acid. The solution is saturated with HS, and allowed to stand till the odour of this gas disappears. The sulphuret is collected upon a balanced filter, washed, dried at a gentle heat, and weighed. The sulphuret thus obtained requires to be analyzed, unless it is known that the metal existed in solution as antimonic oxide alone. The sulphuret may, for this purpose, be placed in a small weighed porcelain boat or tray, introduced into a porcelain tube, and ignited in a current of hydrogen gas. The metal is then weighed. Or the amount of sulphur in the sulphuret may be found by treating a weighed quantity with strong hydrochloric acid. The sulphur separates in a solid form after long digestion. It is collected on a weighed filter, washed, first with water, to which muriatic and tartaric acids have been added, and then with pure water. It is finally dried at a very gentle heat, and weighed. Antimonious acid may be estimated by dissolving in an excess of hydrochloric acid, adding sodiochloride of gold, and keeping the whole for several days in a warm place. After a day or two the reduced gold is collected on a filter, washed with water acidulated with muriatic acid, ignited, and weighed. If any antimonic acid has separated along with the reduced gold, it is removed by fusing the filter and its contents with carbonate and nitrate of potash, and weighing the gold as a regulus.

Separation of Antimony from Tin.—If, in the metallic state, the alloy is comminuted and treated in a large beaker with nitric acid of specific gravity 1·04, the excess of acid is expelled, and the oxides dried. It is heated to a faint red heat, and fused in a silver crucible with pure hydrate of soda in excess, keeping the mass for some time in a pasty state. The mass when cold is moistened with water, the crucible completely cleansed with water, and the whole poured into a large beaker, in which the sparingly soluble antimoniate of soda is allowed to deposit. Stannate of soda, containing the tin, remains in solution. Alcohol of specific gravity 0·83 is now added in the proportion of one volume to three of water.

The whole is well mixed, and set aside to deposit. The antimoniate of soda is entirely precipitated, and is filtered off and washed, first with equal volumes of water and alcohol of 0·83, and at last with a spirit formed of three volumes alcohol of the above strength to one volume water, until the filtered liquid, acidulated with sulphuric acid, no longer gives a yellowish precipitate with HS, even after long standing. A very small quantity of carbonate of soda should be dissolved in the weak washing spirit. The filtrate is now gently heated to expel alcohol, diluted with water, supersaturated with sulphuric acid, precipitated by HS, and the sulphuret of tin converted into oxide. The antimoniate of soda is dissolved in a mixture of muriatic and tartaric acids, and the antimony precipitated by HS.

From mercury, silver, copper, bismuth, lead, cadmium, cobalt, zinc, iron, and manganese, antimony is separated by dissolving the compound in a small flask in strong hydrochloric acid, or, if necessary, in nitrohydrochloric acid. The solution is concentrated, supersaturated with ammonia, mixed with hydrosulphate of ammonia, and digested at a gentle heat, the flask being corked up. When the precipitate has become quite black, and the solution contains no manganese, zinc, or cadmium, the whole is cooled, diluted with water, and filtered. It is washed uninterruptedly with water containing a little hydrosulphate of ammonia. From the filtrate the antimony is thrown down by adding dilute hydrochloric acid.

Or the compound is fused with sulphuret of sodium, and treated with water. A double sulphuret of sodium and antimony is dissolved, whilst lead, &c., remain insoluble. If gold or platinum be present, a weighed portion of the alloy is heated in a current of chlorine gas in the apparatus already figured. The bulb tube in which the alloy is placed is weighed, first alone, and then along with its contents. One of its limbs is then bent down at right angles, and allowed to dip into a flask half full of a dilute solution of tartaric acid with a little muriatic acid. The tube plunges just below the surface of the liquid. Heat is applied with great care, lest the liquid in the flask should ascend into the bulb, and, as soon as incandescence appears, the lamp is removed. The chloride of antimony distils over into the flask, to the contents of which must be added the washings of the bent limb of the bulb tube, which should be cut off. The other metals remain in the bulb as chlorides, and are separated by the rules laid down above.

From uranium, cobalt, zinc, iron, and manganese, antimony may be separated by adding tartaric acid to the dilute acid solution, and passing a current of HS through it, so as to throw down the antimony as sulphurets. In separating the mixed metals contained in the filtrate, it is needful to add ammonia and then hydrosulphate of ammonia. If nickel is present, tartaric acid should not be used.

From the earths and alkalies antimony may be separated by sulphuretted hydrogen. The presence of tartaric acid must be avoided.

Antimonic and antimonious acids, according to Rose, may be estimated by dividing the solution into two portions, determining the total amount of antimony in the one, and ascertaining the amount of antimonious acid in the other, by perchloride of gold. Gold is reduced proportionate to the antimonious acid in the solution. No nitric acid must be present.

N.B.—According to Rose, the compound usually termed antimonious acid, $Sb\,O_4$, is an antimoniate of oxide of antimony, $Sb\,O_3$, $Sb\,O_5$. The compound $Sb\,O_3$ he terms antimonious acid or oxide of antimony, according as it plays the part of acid or of base.

TUNGSTEN.

Where tungstic acid exists in solution, unattended by other fixed matter, it is merely needful to evaporate to dryness, to ignite and weigh the residue.

From mercury, silver, copper, uranium, bismuth, lead, cadmium, nickel, cobalt, zinc, iron, and manganese, tungstic acid may be separated by reducing the mass to an impalpable powder, and digesting in muriatic acid. The tungstic acid which separates is filtered, washed, ignited, and weighed. A portion of the acid, however, dissolves along with the oxides. The solution is therefore rendered ammoniacal, and mixed with hydrosulphate of ammonia, which precipitates the other oxides, whilst tungsten remains in solution as persulphuret. The liquid is evaporated to dryness, and the residue, after ignition, is added to the amount before obtained.

Oxide of tungsten is readily converted into tungstic acid by prolonged digestion in hydrochloric acid.

If the compound be insoluble in acids, it is pulverized, mixed with four times its weight of bisulphate of potash, and fused in a platinum crucible at a low red heat. On treating the mass with water, the metallic oxides, with a trace of tungsten, dissolve, whilst the larger portion of the tungstic acid remains insoluble. The subsequent treatment is as above, by means of ammonia and hydrosulphate of ammonia, the tungstic acid being estimated as above. From metals whose sulphurets are soluble in hydrosulphuret of ammonia, tungstic acid has not yet been accurately separated.

Early tungstates are decomposed by an acid, and the mass treated with ammonia. Tungstic acid dissolves, whilst the earths are precipitated. Lime, strontia, and baryta are likewise separated by decomposing with an acid, digesting with carbonate of soda, and boiling. The earths are thrown down as carbonates, and tungstic acid remains in solution. If silica be present, the whole, immediately after treatment with an acid, may be drenched with excess of ammonia. Silica alone remains undissolved, and is rapidly separated by filtration. The filtrate is then treated with an alkaline carbonate as above.

Alkaline tungstates are fused with sulphur, and heated in a current of chlorine. The tungsten is carried away as chloride, and estimated as loss.

Separation of Tungstic Acid from Oxide of Tin.—The mixed substances are weighed and ignited in a porcelain crucible, into which a current of dried hydrogen gas is passed through a hole in the cover. The mass is then boiled in hydrochloric acid, and the tin precipitated as sulphuret, by sulphuretted hydrogen from the filtered solution. The tungstic oxide is converted into acid by roasting in the air.

MOLYBDENUM.

Molybdenum, when existing unaccompanied by other fixed matter, is best determined as oxide. The acid is placed in a platinum tube, and heated at a moderate temperature in a current of hydrogen. From alkalies it is separated by neutralizing with nitric acid, and precipitated with protonitrate of mercury. The precipitate is allowed to settle for some hours. It is then collected on a filter, washed with a very dilute solution of protonitrate of mercury, dried at 212° F., and weighed.

From the heavy metallic oxides already mentioned, molybdenum is separated by dissolving in an acid, rendering the solution ammoniacal, and digesting with hydrosulphate of ammonia in excess. The undissolved metallic sulphurets are filtered off, and sulphate of molybdenum is precipitated from the filtrate by means of muriatic acid.

If the molybdate be insoluble in an acid, it is fused with the bisulphate of potash.

From the earths malybdic acid is separated by treatment with nitric acid and evaporation to dryness. Molybdic acid remains insoluble, whilst the nitrates are taken up with water.

VANADIUM.

Vanadium, when existing alone or with volatile matter, is reduced to suboxide by ignition in a current of sulphuretted hydrogen, and weighed as such.

From metals whose sulphurets are insoluble in hydrosulphate of ammonia, vanadium is separated, similarly to tungsten and molybdenum. From the solution thus obtained, sulphuret of vanadium is thrown down by an acid, and washed in contact with the air, until converted into vanadic acid.

From lead vanadium may also be separated by fusion with bisulphate of potash. Sulphate of lead is formed, whilst vanadiate of potash remains in solution. With baryta the process is similar.

From the alkalies vanadium is separated by dissolving in muriatic acid, digesting with sugar, precipitating the blue

vanadic oxide with ammonia, and washing with ammoniacal water. The filtrate retains a trace of ammonia, and is therefore evaporated to dryness, ignited, and added to the former portion.

CHROMIUM.

Compounds of chromic oxide are precipitated with ammonia, the solution heated until colourless, and the precipitate filtered off, washed, dried, and strongly ignited. The heat should be applied gradually to avoid loss by projection.

Chromic acid is best reduced by adding muriatic acid in excess, and a trace of alcohol, to the warm concentrated solution. Ammonia is then added as above.

From the bases precipitable by SH, chrome is separated by passing a current of that gas through the solution. It remains dissolved, whilst they are thrown down.

From the oxides of nickel, cobalt, zinc, iron, and manganese, it is separated by fusing the substance in fine powder, with a mixture of nitre and carbonate of soda, in a platinum crucible. Bisulphate of potash may likewise be employed. The chrome is afterwards dissolved out of the fused mass as chromate of potash or soda, whilst the other oxides remain undissolved. Manganese may be dissolved as an alkaline permanganate, which, however, will undergo spontaneous decomposition, the whole being deposited as hydrous peroxide.

Native chrome iron should be reduced to a very fine powder, and ignited for an hour with twice its weight of bisulphate of potash.

If chromic acid is combined with the oxides last mentioned, the mass is fused with an alkaline carbonate, and subsequently extracted with water. An alkaline chromate dissolves.

From alumina chromic oxide is separated by boiling in a solution of caustic potash. Most of the alumina dissolves, while the precipitate of chromic oxide is fused as above with carbonate and nitrate of soda. The alumina which remains undissolved on extracting the mass with ammonia is added to the former portion.

Chromic acid is separated from alumina by ammonia.

From magnesia chromic oxide is separated by fusion with a carbonate and nitrate, the magnesia remaining undissolved on subsequent treatment with water. If chromic acid is present, the fusion is performed with a carbonate alone. From baryta chromic oxide is separated by means of sulphuric acid.

If lime and strontia are present, the compound is fused with three times its weight of mixed carbonate and nitrate of potash. Water dissolves out alkaline chromates, and leaves carbonates of lime and strontia untouched.

When chromic acid is combined with these earths, the mass is fused with an alkaline carbonate, and extracted with water.

When earthy chromates are mixed with earthy sulphates, the compound is treated in fine powder with muriatic acid and alcohol. Chrome dissolves as chloride, whilst the earthy sulphates remain insoluble.

From the alkalies chromic oxide is precipitated by ammonia. Alkaline chromates are dissolved in a little water, heated with muriatic acid and alcohol, the latter dispelled by evaporation, and the chromic oxide precipitated by ammonia.

When chromic oxide and chromic acid exist together in solution, the latter is precipitated by acetate of lead. The liquor should not contain any free acid except the acetic.

A recently precipitated solid compound of chromic oxide and acid, is digested with a solution of acetate of lead containing free acetic acid.

ARSENIC.

Arsenious and arsenic acids, when unaccompanied by any other fixed matter capable of being precipitated at the same time, are determined by neutralizing the liquid (if acid) by ammonia, and adding hydrosulphate of ammonia in excess. The solution, if concentrated, is now diluted with excess of water, and slightly acidulated with muriatic acid. The liquid is digested at a moderate temperature, until all odour of SH has disappeared, and the precipitate is filtered off. The sulphuret of arsenic thus obtained is dried at a very gentle heat, and weighed. All that can be detached from the filter is put in a large flask, and its exact quantity is determined by weighing the filter paper along with any adhering particles. Nitro hydrochloric acid is then poured into the flask. The arsenic present is converted into arsenic acid, and a part of the sulphur into sulphuric acid. The residue of unchanged sulphur collects in little globules, and is thrown upon a balanced filter, washed, dried with great care, and weighed. From the filtrate the sulphuric acid is precipitated by chloride of barium, and the amount of oxidized sulphur is thus ascertained. The amount of arsenic is found by deducting the joint weight of these two portions of sulphur from the weight of sulphuret dissolved. From all bases not precipitated by SH, arsenic in any form is separated by passing a current of that gas through the dilute solution previously acidified with muriatic acid, allowing the whole to stand in a warm place, and examining the precipitate as above.

If traces of copper, bismuth, &c., are present at the same time, the mixed precipitate given by SH, after treatment with aqua regia, is neutralized with ammonia, and then mixed with hydrosulphate of ammonia. The sulphurets of copper, &c., remain untouched, whilst that of arsenic dissolves, and is reprecipitated, after filtration, by the addition of muriatic acid.

From the bases precipitable by SH, arsenic is separated by adding hydrosulphate of ammonia to the solution previously rendered ammoniacal. Prolonged digestion is generally required in a flask not tightly corked.

From baryta, lime, strontia, and lead, arsenic is separated by means of sulphuric acid, alcohol being used for dilution and washing, except in the case of baryta.

Tin and antimony offer peculiar difficulties, their sulphurets, like that of arsenic, being soluble in excess of hydrosulphate of ammonia.

From the latter, arsenic may be separated by deflagrating the mass with thrice its weight of a mixture of nitrate and carbonate of soda. The mass being extracted with cold water, the residue, after ignition, contains all the antimony as antimoniate of soda. Arsenic is thrown down from the solution by SH, and determined in the usual manner.

From both tin and antimony arsenic is separated by oxidizing with concentrated nitric acid (if needful), evaporating to dryness, and fusing in a silver crucible with nine times the weight of hydrate of soda. The fused mass is mixed with a little water, and alcohol of specific gravity 0·83 is added, until one-third the volume of the water has been added. The whole is set aside for twenty-four hours, with frequent stirring, the precipitate is thrown upon a filter, the glass rinsed with alcohol, and the precipitate (antimoniate of soda) is washed, first with a mixture of equal volumes of water and alcohol of 0·83, and then with three volumes alcohol of the same strength, mixed with one of water. The washing must be continued until a drop of the liquid, acidulated with a trace of sulphuric acid, no longer gives a precipitate with SH. The precipitate is dissolved in a mixture of muriatic and tartaric acids, and the antimony precipitated with SH.

The filtrate is supersaturated with muriatic acid, and SH passed through it. It is set aside until the smell of the gas is almost imperceptible, and the precipitate is collected upon a balanced filter. The clear liquid is heated for some time, mixed with a solution of sulphurous acid, and again treated with sulphuretted hydrogen. A further quantity of arsenic is generally precipitated, and is kept separate, and only added to the arsenic of the former precipitate when separated from the tin. This is effected by heating the whole in a current of sulphuretted hydrogen. Sulphuret of arsenic sublimes, whilst sulphuret of tin remains unvolatilized. The tin is converted into oxide, and the arsenic into acid. When arsenious and arsenic acids occur together in solution, the former is determined by adding the sodiochloride of gold. Metallic gold is separated in proportion to the arsenious acid present. By deducting the amount thus obtained from the total quantity of arsenic present, the proportion of arsenic acid is found.

TELLURIUM.

This metal, when present as tellurous acid, is reduced by adding sulphite of ammonia to the solution, which, if alkaline,

is first acidified by muriatic acid sufficient to dissolve the oxide at first precipitated. The liquor is heated (not boiled) in a small flask, and a small quantity of the alkaline sulphite is gradually poured in. The liquor should be tolerably concentrated. Tellurium falls as a bulky black powder. It is gathered upon a balanced filter, dried at a very gentle heat until no further loss is perceived, and then weighed. In filtering, the contact of the air should be avoided. The clear liquid from the flask is first poured upon the filter, and the tellurium should not be poured out until washed in the flask with water containing a trace of sulphurous acid.

The filtrate should be tested with a fresh proportion of sulphite, in order to ascertain whether all tellurium is removed.

Nitric acid, if present, must be previously expelled by heating with muriatic acid for a considerable time. Telluric acid is reduced to tellurous acid by treatment with hot muriatic acid, and determined as above.

Telluriates may be determined by adding nitrate of silver in slight excess, dissolving the precipitate in ammonia, and evaporating. Basic tellurate of silver falls, and is collected on a weighed filter, and weighed. 100 parts of this salt contain 20·2 of telluric acid.

From mercury, silver, copper, bismuth, lead, and cadmium, tellurium may be separated by saturating the solution with ammonia, adding hydrosulphate of ammonia in excess, and digesting for a considerable time at a gentle heat. Sulphuret of tellurium dissolves.

Alloys of tellurium, with any of these metals, are dissolved in nitric or nitromuriatic acid, and treated as above.

From tellurium, silver may be removed by muriatic acid.

From gold, and from many of the foregoing metals, tellurium may be separated by heating the mixture in a current of chlorine gas. Chloride of tellurium sublimes, and is collected in a flask containing water, with a little hydrochloric acid. The tellurous acid in the flask is estimated with a sulphite.

Antimony, tin, and arsenic may be separated from tellurium by precipitating the latter with an alkaline sulphite.

From chromium, uranium, nickel, cobalt, zinc, iron, manganese, the earths, and alkalies, tellurium is separated by being precipitated by SH. The sulphuret thus obtained is digested while still moist in nitrohydrochloric acid, the solution is filtered, the nitric acid removed by digestion with more hydrochloric acid, and the tellurous acid reduced by an alkaline sulphite.

SELENIUM.

Selenium is determined exactly as tellurium. The precipitate, at first of a bright red, becomes black on boiling. Great care is required in drying.

Selenic acid may be at once determined by adding nitrate of baryta. The insoluble seleniate of baryta is precipitated. Any selenious acid present may be peroxidized by fusion with an alkaline nitrate. From bases not precipitable by SH, selenium is separated by its means. The sulphuret, whilst still moist, is placed in fuming nitric acid until completely dissolved. All nitric acid present is then destroyed by muriatic acid, the liquid is diluted with water, and the selenium precipitated by a sulphite.

If the metals are in the reguline state, the whole is dissolved in nitric or nitromuriatic acid, and treated further as above.

If the selenium be combined with these substances in the form of selenic acid, it is determined as seleniate of baryta. Or if the compound be insoluble, it is boiled with muriatic acid until converted into a selenite. Otherwise a known weight of the insoluble compound is ignited in a platinum crucible with a fourfold amount of carbonate of soda. From the fused mass water extracts seleniate of soda, the acid in which may be determined by baryta.

From mercury, silver, copper, bismuth, lead, and cadmium, selenious acid is separated by neutralizing the compound, if acid, with ammonia, and adding hydrosulphate of ammonia in excess, in which sulphuret of selenium dissolves.

Seleniates of the same bases are treated with SH and filtered. The selenic acid is then thrown down from the filtrate by nitrate of baryta.

From metals whose chlorides are fixed, selenium may be separated by heating the compound in a current of chlorine gas.

We thus conclude the determination of the metals in their various compounds and mixtures. Into the processes required for the estimation of the non-metallic elements, want of space forbids us to enter.

HISTORY OF THE PHYSICAL SCIENCES.

CHAPTER IX.

THE ONWARD MOVEMENT.—(*Continued.*)

SIMILAR to Campanella, in many respects, was Giordano Bruno, the haughtiest, the most chivalrous, we might even say the most romantic, of the innovators. Having already devoted some space to an account of his life and sufferings, we have merely to explain his peculiarities as a philosopher. Although an opponent of the Aristotelians, his system departs not from observation, but from ideas. It is, in fact, a revival of Platonism, tinctured by the imaginative mysticism of the East. Nevertheless we find him ably and zealously defending the Copernican system of astronomy. The motion of the earth, which the sage of Thorn had merely put forward in the light of an hypothesis, Bruno pronounced a necessary truth. With this he insisted strongly upon the plurality of worlds, and the immensity of the universe. The narrow bounds set to creation by the monks, in harmony with their own narrow faculties, were swept away by his acute logic and his lofty imagination. Like Campanella, he was filled with enthusiasm for the unity of all science, the great synthesis which shall once crown all intellectual labour. In this hope he developed the *Ars Magna* of Lully, as a general method of invention, an infallible instrument of scientific reward, a mechanism for thinking and speaking. What the logic of Aristotle had seemed to the peripatetics, this *great art*, thus fortified and enriched, was to be to future generations.

The science thus built up, should not be, according to Bruno, a mere incoherent collection of experimental data, and of traditions. It was to embrace, in an inflexible order, all the essential elements of the eternal nature of things, all possible forms of being, all that the threefold study of God, the world, and man could attain, whether by the senses or by reason. In this cyclopædic organization of human ideas, the reason rather than the senses was to determine the office, the rank, the bearings, the value, the signs of each conception. It was by gathering the fundamental ideas of reason, that we could succeed in constructing the totality of human knowledge, in tracing the plan and the genealogy of science. To know and to discuss everything, it was sufficient to imprint this plan upon the memory, and, by exercising this faculty, to find with ease and certainty the *place* of each notion, its branches, and its roots. Thus, whilst actively combating the peripatetic-scholastic doctrines, and whilst maintaining those grand germ-ideas of modern science, the mobility of the earth and the immensity of the universe, Bruno differs in certain well-marked features from his fellow-labourers. Whilst they proclaim, with greater or less distinctness, the importance of experiment and observation, Bruno strives, on *à priori* principles, to detect the laws of nature in the ideas of the human reason; thus allying himself to the Platonists, to the Alexandrians, and even to the students of the Cabbalah. In his version of Lullism, as in the Cabbalah, all beings are explained by the Divine Being from whom they emanate, and which they imply; the world spiritual is supposed to exercise a powerful, almost magic action upon the world material. The inspiration which we share by entering into relation with the Deity, enables us to classify and interpret all phenomena and all ideas. If reason be unable to recognise in the created world the unity of the uncreated Word, it is permitted, and even commanded, to make use of symbolism. But what recalls most strikingly in Bruno the oriental philosophy is, the employment of a so-called "moral interpretation," whenever an attribute will not combine logically and naturally with a subject.

His classification of the sciences are various, and depend upon a variety of principles. Thus, recognising in the soul three faculties—will, understanding, and sense—he arrives at the following arrangement:—

WILL, or moral science,..................	Ethics. Economics. Politics.
UNDERSTANDING, or speculative sciences,	Physics. Mathematics. Metaphysics.
SENSE,* or organic sciences, ...	Grammar. Rhetoric and Poetry. Logic.

The distinction between intelligence and memory, led him to the following system:—

Passive understanding, or memory,...............History.
Active understanding, or intelligence,............Speculation.

By history, Bruno understands here the knowledge of phenomena and facts as embraced by the senses. By speculation, he signifies the investigation of causes and ideas.

Proceeding from the idea of *means* and *end*, Bruno arrived at a classification upon which he laid more weight than upon the preceding. It is as follows:—

Instrumental or organic sciences,	Grammar. Rhetoric. Logic.
Principal or real sciences,	Physics, Mathematics, and Metaphysics. Ethics, Economics, and Politics.

Mathematics he divides into arithmetic, music, geometry, astronomy, perspective and painting, physiognomy and astrology.† To physics he attaches magic, chemistry, medicine, and agriculture. Metaphysics he considers as one and indivisible.

Bruno does not separate, with the precision of the younger Bacon, philosophic knowledge, properly so called, from the preliminary and auxiliary studies which philosophy requires. Though he does not insist with the energy of the English sage upon observation and induction, he still assigns to the experimental sciences an important place in his encyclopædic arrangement. He agrees with Descartes rather than with Bacon, in judging every science impossible which seeks to establish itself independently of the idea of a being of sovereign perfection and absolute necessity.

Julius Cæsar Vannini, the latest and least sincere of the Italian innovators, was born at Taurozano, in the kingdom of Naples, about A.D. 1585. He studied philosophy at Rome under John Bacon, a disciple of Averroes, and devoted much attention likewise to physics, medicine, astronomy, astrology, civil and ecclesiastical law, and theology. During his college years, he underwent great hardships from poverty. He next travelled through France, England, Holland, and Germany, as was customary with students in that age. His *Dialogues on Nature*, published in Lyons, 1616, excited the anger of the Sorbonne, and was ordered to be burnt. He wrote also a variety of works on physics, medicine, magic, astronomy, and philosophic method. These, however, are unfortunately no longer extant, and it has been doubted whether they were all actually published.

His speculations seem to have been mainly directed towards theological and metaphysical subjects, and, as such, do not come under our consideration. His philosophic ideas are obscure, confused, and erroneous. He still clings to the old scholastic dream, that the whole universe exists for the convenience of our earth, and that man is the measure of all things. He believed in astrology, in the doctrine of sympathies, in the divining rod, and, had he lived in our days, would have been a redoubted table-turner and spirit-rapper. He combats the systems of Aristotle, of Averroes, and Cardanus. Still, his main claim to a place among the reformers of science lies in the simple fact, that he was burnt to death as an innovator. Hence we judge that the enemies of intelligence must have found in his oral teachings, or in those of his works which have perished, something of greater value than has come into our hands.

Before passing on to the consummation of the intellectual reformation, as effected by Bacon and Descartes, we must review a number of detached thinkers, who made important progress either in general philosophic method, or in some particular science.

The history of astronomy having been given in an earlier portion of the present work, we need but mention the names of Copernicus, Kepler, Tycho, and Galileo. With these are associated certain names less known, but perhaps not less worthy. Fra Castori, the rival of Copernicus, and Magini, the valued friend of Kepler, hold a prominent place amongst the constellations of genius which then adorned Italy. A yet higher rank must be assigned to Paolo Sarpi, the friend and master of Galileo. Although a monk, he was the avowed champion of free inquiry, and his influence long preserved Venice from the intrigues of the Jesuits. He protected the unfortunate Bruno, and it was only during his absence that the familiars of the Inquisition could secure the extradition of that daring thinker. As might be expected, he was cordially detested by the friends of traditional authority. One evening he was waylaid by four assassins, who pierced him with numerous wounds, and then took refuge in the mansion of the Papal nuncio. Sarpi, however, recovered, and hung up in his cell a dagger which had been left sticking in his body, with the inscription, "A present from Rome."

In addition to his astronomical researches, he cultivated physics, natural history, and medicine with success.

In the comprehensive and important science of physics, an active movement was commenced. The doctrines of Aristotle and his school on equilibrium, on pressure, and motion, were carefully scrutinized, and found to be erroneous. A number of men come forward who, with little reference to general philosophy, institute experiments from a practical point of view, and attain a more correct insight. Here also, as well as in speculative reform, Italy takes the lead. Leonardo da Vinci, illustrious as an artist, with the versatility so frequent in his country, attained also eminence in science. His occasional practice as an engineer, led him to speculate on mechanics. He investigated with success the conditions of equilibrium of oblique forces; he states with accuracy the proportion of the forces exerted by a cord which acts obliquely and supports a lever, and distinguished soundly between real and *potential** levers; and he asserted that the time occupied by any body in descending an inclined plane, is to the time of descent down the vertical side as the length of the plane is to its height. He was unable, however, to furnish the proof. In mathematics, optics, and meteorology, he likewise occupied an eminent rank. On philosophic method, his views are so just and luminous, that we must deeply regret their remaining unpublished. We find in his manuscripts the following expressions:—"Theory is the general, experiments are the soldiers. Experience, who never is deceived, explains the artifices of nature. Sometimes our judgment is deceived, because we expect effects which experience will not allow. We must consult experience, and vary the circumstances, till we have drawn from them general rules; for by her true rules are furnished. But you ask, of what use are rules? I reply, they direct us in the investigation of nature and the operations of art. They save us from imposing upon ourselves and others, by promising results which we cannot obtain. In the study of the mathematical sciences, those who consult authors instead of nature, are not the children of nature, but only her grandchildren. She is the true teacher of men of genius! But see the absurdity of men! They turn up their noses at him who prefers to learn from nature herself, rather than from authors who are only her clerks. Nature

* We are here reminded of the encyclopædic classification of Locke, whose semiotics, physics, and practical science, correspond respectively to the organic, speculative, and moral science of Bruno.

† The reader will perceive the confusion between *sciences* and *arts*, which at that time were not clearly distinguished, even by the most advanced thinkers, and which are still blended together by undisciplined minds. Thus we hear horsemanship, navigation, penmanship, war, medicine, and, *proh pudor!* pugilism and foxhunting, absurdly designated as sciences.

* Perpendiculars drawn from the centre, upon the direction of forces.

begins from the reason, and ends in experience; but for all that, we must take an opposite course, beginning from the experiment and seeking to discover the reason." The value of these precepts will be more striking, if we reflect that the philosophical works of Leonardo are dated 1498. This illustrious man, whom Humboldt pronounces the first physicist of the age, flourished from 1442 to 1520. Next, we perceive Cardanus, highly gifted, profound, but decidedly eccentric, and slightly tainted with quackery. He was born 1501, and died in 1576. In his memoirs, we find strange and racy traits of the olden time. Playing at dice with a casual acquaintance, he lost his money, whereon, says the rough and ready old philosopher—"I wounded him in the face with my dagger, but slightly, and took from him not my money alone, but his own also, and therewith departed." Besides such freaks, he was escorted by a familiar spirit, whose suggestions were of wonderful aid in his medical practice. He believed likewise in magic, in all mysteries, and to an exorbitant degree in himself and his own perceptions. His labours as a mathematician, especially an algebraist, were meritorious and successful. In physics he maintained, contrary to the received doctrines of the age, that cold is the mere absence of heat.* Light and heat he regarded as closely connected, if not convertible. He recognised the distinction between an insular and a continental climate, noticed the intensity of light in the southern hemisphere, and endeavoured to ascertain the comparative elevation of the snow line in different latitudes.

Giovanni Batista Benedetti, a Venetian nobleman, published in 1599 a work in which the Aristotelian dogmas on motion and weight are ably refuted.

Stevinus, of Bruges (1548—1620), an engineer and mechanician, may be said to have constituted an era in this branch of science. He, for the first time, clearly apprehended the distinction between statics and dynamics.† He established the fundamental laws of equilibrium, from a consideration of the inclined plane. He advanced very correct views on the equilibrium of fluids, restoring the doctrines of Archimedes. He shows that the pressure of a fluid on the bottom of the vessel, may be greater than the weight of the fluid; he determines the pressure upon oblique bases.‡ In short, under his hands the statical portion of barology § received its definite constitution.

Michael Varro, of Geneva, made some progress in dynamics.

Francis Maurolycus, of Messina (1575), may be noticed as a reformer in optics; yet, in many respects, his views were exceedingly limited, since he declares Copernicus "more worthy of a scourge than of a refutation." In the doctrines of light and heat, little however was done until a later epoch. It is therefore the more surprising, that the study of polar forces ‖ received such powerful impulse from our countryman, Gilbert. William Gilbert was born at Colchester, became physician to Queen Elizabeth and to James I., and died in 1603. In his principal works, *De Magnete* and *De Mundo Philosophia Nova*, he declares magnetism and electricity two forms of a single fundamental force pervading nature. He considered the earth itself a magnet, and ascribes the lines of equal magnetic declination and inclination to the configuration of continents and the depth of oceans. His view of the magnetic properties of all matter, has been confirmed by the recent discoveries of Arago and Faraday. He traced the magnetic condition of iron rods after long exposure in an upright position to its true cause, the influence of the earth. The polarity of the needle, its attractive and repulsive action, its variations from a true northern direction, and its declination—facts unknown to the ancients, were to him perfectly familiar. He gives from experiment a tolerably extensive list of bodies capable of displaying electric action when rubbed. In addition to these special discoveries, his opinions on general philosophy, incidentally declared in the works just cited, are of the most clear and advanced order. He maintains the superiority of experimental research over vague conjecture. He observes that, in searching out the hidden causes of things, stronger reasons are obtained from trustworthy experiments and demonstrable arguments, than from probabilities and dogmas. Whilst duly appreciating the philosophy of the Greeks, he claims the right of extending and continuing what they had begun. He accepts the Copernican doctrine, and treats the contrary view as totally absurd. A short history of science prefixed to the *Nova Philosophia*, is remarkable for the general soundness of its principles. Francis Bacon, it must be owned, was eminently unjust to his illustrious countryman, and even treated his exact magnetic inquiries with ridicule.

Chemistry, more complex than physics, had greater difficulty in attaining a definite constitution, and even to a late period it remained involved in the generalities of the school philosophy, in the teachings of the antique and oriental pharmaceutists, in the operations of the empirical arts, and lastly, in alchemy. Its creation, as a science, is, perhaps, mainly due to a man of gigantic though ill-governed intellect, Theophrastus Paracelsus von Hohenheim. This eccentric character was born about 1493, at Einsiedeln, near Zurich. In a short and unsettled life he operated the decomposition of alchemy—a pursuit which he had followed in youth, but which he, in after years, renounced as delusive. *Gold-makers*, indeed, are still to be met with during the two next centuries, but these are swindlers rather than sages. Philosophic alchemy had ceased, and in its stead chemistry had appeared. Of this science, Paracelsus was the first public teacher. His lectures were delivered, not in Latin, but in German—another interesting circumstance. By this innovation, he threw open the gates of learning to the people, and all diffusers of useful knowledge, promulgators of cheap literature, and champions of popular education, may hail in him their great forerunner. Furthermore, to express most clearly his dissent from the established doctrines of the age, he solemnly burned before his audience the works of Aristotle, of Avicenna, Galen, and other recognised authorities, and proclaimed that henceforth men should seek after truth in things rather than in words.* His own mental training had depended more upon observation than upon reading; he had travelled from Sweden to Egypt, and from Spain to Tartary; he had examined mines, foundries, dye-houses, and glass-works; he fraternized with gypsies, to learn their medical secrets, and pried wheresoever anything was to be learned. He showed a foretaste of the practical leanings of modern science. Instead of deeming, like his predecessors, the arts and manufactures below the notice of the philosopher, he declared that, in those neglected regions, the most important and interesting facts might be witnessed. In medicine, he combated the doctrines of the Galenists, who were in the habit of treating all diseases with decoctions of crude herbs, and sought to extract from all substances their active principle. Hence he might be said to have given the first impulse to organic chemistry. Further, he speculated, wildly and imperfectly, we must own, on the chemical processes involved in animal life, especially on digestion and nutrition. Here is the germ of physiological chemistry.† The number of chemical facts elicited by his activity is, to be sure, not great—the principal being the distinct metallic nature of zinc, and the existence of gases. What he gave to chemistry was an object, an impulse, a distinct and tangible function. To prepare the concentrated principles which he had introduced into medicine, all known bodies were put to the question in every way that could be devised, and legions of facts were, in consequence, ascertained. Though his chemistry still wears the garb of the primeval period—

* The error of ascribing to cold an actual and independent existence, has been revived by Forfar, in a work styled *Trinology*.

† Statics, the doctrine of equilibrium of forces counterpoising each other; dynamics, of free forces exerting themselves in motion. This, or a closely analogous distinction, may be traced in every science. Thus, in the science of organic life, we term the statical portion, anatomy; the dynamical, physics. In chemistry, the dynamical phase is as yet undeveloped.

‡ This he accomplished by a mathematical method, resembling the infinitesimal calculus.

§ Barology comprises that portion of physics commonly denominated mechanics, hydrostatics, and pneumatics—the terrestrial phenomena due to gravitation and to non-molecular motion.

‖ The polar forces, electricity and magnetism, exert themselves equally and similarly in opposite directions.

* That his condemnation of antiquity was not a blind, sweeping prejudice, appears from the veneration which he paid to Hippocrates, to whom he urged the student to return, disregarding the additions of later commentators.

† Though condemning the urinoscopists (water-casters) of the day, he strongly insisted on the value of a chemical analysis of urine in the diagnosis of diseases.

though he personifies the elements and their forces (even digestion is with him a demon or god, the *Archeus*), he yet declares his conviction that, in future times, the seemingly supernatural will be accounted for by strictly physical laws. Thus far we have seen only the bright side of this great man's character—we have recognised in him the reformer of philosophic method, the scorner of vain authority, the promulgator of science to the people, the founder of chemistry. Had he been merely this, he might have anticipated Francis Bacon, and reigned for ever as the lawgiver of the intellectual world. But he was impatient, vain-glorious, the slave of a vivid and uncontrolled imagination. He could not wait for the slow development of science through successive ages, but sought to consummate at once the work just begun. He declared himself divinely taught, in possession of the universal medicine—the elixir of immortality. We have every reason to believe that he entertained sincere hopes of soon obtaining this grand secret. The astonishing success which attended his medical practice, both supported his confidence, and maintained him in public credit. To fortify his mind for the arduous task of discovering the elixir, he had recourse to alcohol and opium, stimulants whose dangers were then little known. The result may easily be conceived. One of his most eminent patients, Frobenius, died, whereupon all whom professional jealousy and love of old doctrines had made his enemies took courage and denounced him. He quitted his professorship at the university of Basel,* and wandered through Central Europe, accompanied by a small band of his more enthusiastic disciples. Worn out at last by hardships, by dissipation, and by severe though ill regulated thought, he took refuge in the hospital of St. Sebastian, at Salzburg, and there ended his strange career. Paracelsus claims our notice, likewise, in the strange character of a prophet. He foretold that he should rise again from the dead. Strange to say, this prophecy was literally believed by the chemists of the succeeding age. More than a century after his death, Glauber, no visionary, but a clear-headed practical man, published a commentary on these prophecies. In our opinion, Paracelsus does not claim a personal bodily resurrection, but merely announces the continuance of the spirit of scientific research, and of the rejection of arbitrary authority. In another passage he speaks of "Elias the Artist," who should shortly appear as the revealer of secrets—a prophecy which may either refer to Francis Bacon personally, or, more probably, to the inductive method generally considered.

Amongst the followers of Paracelsus, we mention Leonhard Thurneysser zum Thurn, a metallurgist of some merit, though deeply tinctured with quackery.

Libarius, although in some respects an opponent of the Paracelsians, was yet, unknown to himself, influenced by the master spirit of the chemical world. He was aware that the fumes of sulphur blacken lead, that sulphur may be converted into an acid liquid by treatment with nitric acid, and that alcohol is obtained from the juices of sweet fruits. He discovered the bichloride of tin, still called by some, "*fuming liquor of Libarius.*" He used fluor spar as a flux for metallic ores; he formed artificial gems by combining glass with metallic oxides, and knew, especially, that gold communicates to such pastes the colour of ruby. He experimented on the recovery of the portions of metal contained in furnace-slags. In medicine, he is plainly a follower of Paracelsus, rejecting the Galenical slops, whilst seeking diligently to extract the effective principles of plants and minerals. He flourished about the close of the sixteenth century.†

Of very similar views was Angelo Sala, of Vicenza, afterwards physician at the court of Mecklenburg-Schwerin. He also, whilst following out the impulse given by Paracelsus, and developing the germs of positive science contained in his system, combated the visionaries who professed themselves Paracelsians. He was acquainted with fulminating gold with sulphuret of gold and glass of antimony, with the preparation of sulphuric acid from sulphur, and with the nature of sal-ammoniac. He was the first to describe the precipitation of copper from its solutions by metallic iron.*

The greatest, as well as the most devoted disciple of Paracelsus, was, however, John Baptista von Helmont, Baron of Merode, Royenbosch, Oorschot, and Pellines. This patrician chemist was born at Brussels, 1577, and educated at the college of Louvain. He soon became dissatisfied with the classical and scholastic learning of the times, and plunged eagerly into the study of natural science. Whilst in this frame of mind, he became acquainted with the writings of Paracelsus —a circumstance by which all his future intellectual life was modified. After travelling through part of France and Italy, he retired to his estate at Vilvorde, and spent the remainder of his life in physical and chemical investigations. He died on the 13th of December, 1644, in the sixty-seventh year of his age. His place in the history of science is remarkable. He closes the procession of mystical thinkers as far as chemistry is concerned, or, rather, he operates the transition from the primitive personifying to the metaphysical epoch of that science. If, in his chemico-physiological speculations, he, like Paracelsus, placed the various functions of life under the superintendence of a series of Demons or Archei, classified in hierarchical order, he, at times, exhibits these very beings stripped of their personality, and scarce to be distinguished from the "imponderables," from "affinity," and other abstractions of the metaphysical stage. Thus, his vegetable Archeus, *Lefas*, is merely what some, in later days, would call vegetable "vital force." His *Aura Animalis* is the "vital principle" of animals. His *Burr*, which presided over minerals, is the "affinity" of later days. Nay, he even speaks of "elective affinity," and of the saturation of an alkali by an acid.† Another Archeus, by the way, which dominated the celestial movements, has a strong resemblance to the Newtonian gravitation.

In his experiments on the composition of glass, he made use of the balance for the quantitative determination of the silica in glass.‡ He firmly grasped the idea of the indestructibility of matter, showing that salt taken up by water, and silver dissolved in nitric acid, do not cease to exist. He prepared aqueous sulphurous acid, ammoniacal gas, and soluble silica. He treated of the refining of sugar by means of lime and clay, and even attempted organic analysis. His method, which was destructive distillation, led, of course, to no satisfactory results. The gases, likewise, engaged his attention, and, although he had no convenient means for collecting them, he made many remarkable observations. He obtained carbonic acid (*gas sylvester*) by the combustion of charcoal; he clearly distinguished it from atmospheric air, and from steam. He established its identity with the gaseous products of fermentation, the suffocating air of mines, the bubbles given off by mineral waters, and the gas expelled from calcareous bodies by acids. He ascertained its property of extinguishing flame and destroying animal life. Proceeding thence to the study of other gases, he laboured upon the sulphurous, the ammoniacal, the nitrous (obtained by the action of nitric acid upon silver), and *fire gas*. As this last was prepared by heating saltpetre, it must have been impure oxygen. He first ascertained the nature of flame, terming it a gas which is burning. He explains the phenomena of explosion as the sudden resolution of a solid or liquid into the gaseous state. He ascertained the distinction between air and steam, showing that the latter was permanently condensible, the former not. For the measurement of heat, he took as standard points the melting of ice and the boiling of water. As elements, he admitted two substances, air and water, the latter of which, misled by some experiments on the nutrition of vegetables, he supposed could be converted into earth.

* His more immediate reason for leaving Basel was singular. A dignitary of the cathedral, the Canon Cornelius, afflicted with gout, applied to Paracelsus for relief, and promised a fee of one hundred florins. A few pills effected a cure, when behold, Cornelius thought fit to repudiate. The case was brought before the senate of the city, and these worthies in true Dogberry style, decreed that the canon was bound to pay merely the value of the pills consumed. This is the first legal decision on record in favour of the "drenching system." Paracelsus, enraged, denounced the bench in his usual emphatic style, and found it, in consequence, needful to take his speedy departure.

† His system of chemistry, *Alchymia e dispersis*, was published, Frankfort, 1595.

* His collected works, *Opera quæ extant*, appeared at Frankfort, 1682.

† In speaking of the precipitation of silica from its alkaline solutions by the addition of an acid: "quæ saturando alkali sufficit."

‡ "Inveniet statim in fundo arenam sidere eodem pondere quæ prius faciendo vitro aptatur."

Such, in brief, are the leading views of this remarkable man—views which, if successfully followed up, would have superseded Stahl and Beecher, and the whole phlogistian epoch, and anticipated the researches of Scheele, of Priestley, and Lavoisier.

We must not omit to mention, that like most original thinkers of the middle ages, he felt the ill-will of the clerical authorities. His collected writings were published by his son, Francis Mercurius von Helmont, in 1648. Thus far the advance of chemistry in the pre-Baconian epoch. It has now attained a distinct and definite constitution, and having completed its supernatural period, is ready to enter upon the metaphysical stage.

Physiology, more complicated, is less advanced. Among the earliest anatomists of modern Europe, were Mondino, of Bologna (1315), Achillini, Carpa, Messa, Sylvius, and Etienne. Vesalius, a native of Brussels, professor at the university of Padua, made great progress in human anatomy—a department strangely neglected by the ancients. His great work, *De Humani Corporis Fabrica*, is even yet admired, both for its scientific value and for the beauty of its illustrations. The figures are said to have been designed by Titian.

His successor, Fallopius, wrote on the veins, but had no idea of the circulation of the blood.

Servetus (burnt to death at Geneva, 1553, by command of Calvin) speaks of the lesser circulation of blood, from the heart to the lungs, and back to the heart. The same discovery is claimed by Realdus Columbus, a pupil of Vesalius, in his work, *De Re Anatomica*, 1559. The most advanced notions of the age on digestion and nutrition, were involved in the chemico-physiological speculations of Helmont, which, be it remarked, lead by a direct filiation to the modern researches of Liebig and Mulder.

It was not until the great discovery of Harvey, which falls in the post-Baconian epoch, that physiology can be said to have assumed a definite constitution; and even to the present day, its province has been greatly infringed upon, both by chemistry, and by the medical art.

The secondary sciences have made little progress. Botany and zoology were, in this period, studied merely for pharmaceutical purposes, to which the ponderous herbals, published in most countries, bear witness. Belon, born in 1517, is the only zoological writer of merit who can be said to fall within this period. His attentions are chiefly directed to birds. Commencing with land birds of prey, such as the vultures, falcons, &c., he passes to the carnivorous aquatic tribes, the cormorant and albatross. Then follow the waders, the gallinaceous birds, terminating with the ostrich family, and finally, the pigeons, crows, thrushes, and smaller perching birds. This arrangement is very creditable for the time, though in many of the details errors appear.

In geology, Leonardo da Vinci and Fracastori notice the existence and position of organic remains, and combat the common doctrine that these fossils were mere sports of nature, generated by the influences of the stars.

Of the arts, medicine must first claim our attention. We have seen in the history of chemistry, how the Galenical treatment of disease by the administration of simples, was combated by the Paracelsian school, who advocated the use of minerals, especially mercury, antimony, iron, tin, and gold. The vegetables employed were also subjected to a variety of chemical operations, to extract their active principles and free them from inert matter. Hence arose a controversy between the *Galenical* and the chemical schools of medicine.*

Joseph du Chesne (Quercitanus), physician to Henry IV. of France, introduced mineral medicines into that country. On the other hand, Riolanus, Aubert, and Fenot, vigorously defended the old vegetable medicines. The medical faculty of Paris employed their authority to eke out the arguments of the latter, and prohibited, by an official decree, the use of chemical medicines, especially antimony.

In 1603, proceedings were taken against Theodore de Mayerne, for the use of antimonials.*

The views of Paracelsus and Helmont on the chemical functions of the body, attracted much attention in the medical world, and were, finally, developed by Francis de la Boe Sylvius, so as to constitute the iatro-chemical system. This theory accounted for all vital phenomena, physiological and pathological, by chemical considerations. Disease was an unnatural fermentation, or *mixture*. Every fluid of the body was pronounced acid or alkaline, and the remedies chiefly in vogue were acids or alkalies, added to neutralize or correct any such fluid deemed to have lost its normal reaction. Even muscular action was ultimately ascribed to the effervescence of the animal spirits. In opposition to them, arose the sect of iatro-mathematicians, who ran into greater absurdities, endeavouring to account for all vital phenomena by mere considerations of weight, form, and reducing the body to a mere hydraulic apparatus. This controversy belongs mainly, however, to the following epoch. Incidentally, we may remark that the doctrine of the iatro-mathematicians contained a certain approximation to the truth. The crystalline forms of different substances are, to a certain extent, an index to their action upon the human frame—isomorphous bodies having, for the most part, similar effects. Thus the solutions of bodies isomorphous with the saline constituents of the blood, may be injected into a vein to a considerable extent without any serious result, whilst a couple of drops of any other substance, rapidly brings on the most formidable convulsions.

The notion of a universal medicine, elixir of life or catholicon, still maintained its ground, although surrendered towards the close of the period by the more discreet physicians. This doctrine, revived in our times by various quacks, is far less rational than the transmutation of metals. We may be told that all constitutions are radically the same, that all diseases spring ultimately from impurities in the blood; but we must regard such "absolute" assertions as utterly unphilosophic. Are all constitutions *practically* identical? And, even granting the two former propositions, where is the proof that all these impurities can, or should be removed in one and the same manner? The gamboge quacks of the present day are far less rational, and far more impudent, than the mystical physicians of the middle ages.

Another medical view of the period, which still survives in many districts, is the "doctrine of signatures."

Every herb, it was supposed, bore some outward mark, showing the disease to which it was adapted as a remedy. Thus, the black spot on the corolla of the *Euphrasia*, or "eye-bright," resembling the pupil of the eye, we learn that it is a remedy for diseases of that organ. From our present point of view, we might, independently of all experience, pronounce this doctrine radically vicious. It is a manifestation of the old principle, "man the measure of all things." Perhaps in the wonderful land where loaves of bread grow ready baked in the fields, all the treasures of the universe may be ready labelled for the convenience of the inhabitants; but in this work-a-day world no such arrangement exists.

The doctrine of occult sympathies formed another important portion of medical lore—a transformation of the spiritual magic of earlier days. Paracelsus and Helmont appear to have known and practised something very like what is now called "Mesmerism." To heal a wound, it was thought proper to salve and anoint the weapon by which it had been inflicted, although the injured part was, at the same time, to be kept closely bandaged up and protected from the air, and was thus healed by what modern surgeons call the "first intention." The moss gathered from the skull of a gibbeted malefactor was, in like manner, deemed possessed of strange virtues. The following passage from Helmont might be considered rather sarcastic:—"For if a *Jesuite*, put to death by strangulation, or any other kind of martyrdom, be left *sub dio* in an obedient

* The Galenical system is again upheld by the sect of 'medical botanists,' who declaim against all 'mineral medicines,' not aware, probably, that all plants contain mineral matter. Were they to maintain that organic compounds were sufficient for the cure of all diseases, or that only such elements should be introduced into the body, as naturally occur in living beings, such propositions would be, at least, logically self-consistent, and might possibly, on scrutiny, prove correct.

* Theodore de Mayerne, often called by old English authors, Sir Theodore Mayhorn, became physician to our sapient James I., and it is hinted, poisoner to his favourite, Carr, Earl of Somerset. See *Great Oyer of Poisoning*.

position to receive the influence of the stars, yet his head will yield the same crop of moss, equivalent in use, and equally ripe, with the head of a *thief*."—(*Ternary of Paradoxes*, § 41.)

The amount of knowledge possessed on public health was exceedingly meagre, and perhaps at no period of the world's history were sanitary precautions so utterly neglected. Personal and domestic cleanliness, ventilation, except by the negligence of the builder, and drainage, were entirely neglected. On diet, also, the most mistaken opinions, or rather practices, prevailed. The amount of mortality was consequently excessive, and the average duration of life very low.

The arts and manufactures have made considerable progress during this period, though still conducted as mysteries, shunning the light with all the mummery of apprenticeship, journeymanship, guilds, and corporations. New materials had been introduced in consequence of geographical discoveries; public order gave confidence to industry, and increased facilities of intercourse between various countries promoted traffic.

The manufacture of glass, first introduced into Europe by the Venetians, spread first into Bohemia, and thence to France, England, and Sweden. White window glass was first used in Vienna in 1458. The erection of the first glass house in England occurred in 1557. The early specimens manufactured were very imperfect, and tinged a deep green from iron, which could not then be removed. Beautiful specimens of coloured glass for church windows were, however, obtained from Bohemia and Venice. The importance of annealing was understood in Germany in 1625. The alkali employed was generally potash, which was then cheaper than at present, on account of the extensive forests. The glass vessels used by the alchemists in their operations were too thick and heavy—one cause of the many accidents which they experienced.

Magnifying lenses were well known in the fourth century; spectacles were commonly manufactured in 1590; and the first compound microscopes were constructed about 1620, or, according to some authorities, at the end of the previous century. They were ponderous machines, about six feet in length.

The art of pottery seems to have been first introduced into Europe by the Arabs. The Alhambra, erected about 1273, is profusely decorated with earthen tiles and urns. Into Italy, the art was brought about 1415; but the various manipulations and mixtures were independently discovered from 1388 to 1430 by Lucca della Robbia, a sculptor of Florence.

By one of his descendants, the art was carried to France in 1530, but again forgotten—a very frequent result of the "mystery" system—and was rediscovered about 1560 by the celebrated Bernard de Palissy, whose sufferings and struggles, in the perfectation of his art, possess a most tragic interest. A little earlier, earthenware was produced in Nurenberg; but England and Holland did not adopt the art until a later period. The manufacture of porcelain belongs also to a subsequent date.

In metallurgy, and the working of mines, most important advances were made by Georg Agricola, born 1494, near Meissen. In early youth he occupied himself with visiting the mines of Bohemia, collecting and classifying minerals. After a vain attempt to establish himself as a physician, he settled at the mining town of Chemnitz. Not content with reading the remarks of former authors, he collected from the miners practical information as to the best methods of extracting, sorting, washing, and fluxing the ores, and these he endeavoured by careful experiments to improve. His great work, *De Re Metallica*, published in the year of his death, 1555, is justly considered the foundation of modern knowledge on the arts in question. Many of his processes are still in general use. He figures all the tools and machines employed at his time. He treats of assaying, of furnaces, muffles and crucibles; of the fluxes employed; of roasting ores; of smelting; of the processes for extracting antimony, mercury and bismuth; of the separation of gold and silver by quartation, with the preparation of the ingredients; of separating silver from copper, iron, and lead; of refining copper; of the preparation of common salt, saltpetre, alum and green vitriol, sulphur and glass.

Alonzo Barba, a Spanish priest, resident at Tarabuco, in South America, invented the process for extracting gold and silver by amalgamation, as still followed in Mexico. His work was not published till 1629.

Lazarus Erckern, 1588, made some further improvements in metallurgy.

The manufacture of paper was rapidly extending, although the article produced was still coarse, wire-marked, and of a bad colour.

In dyeing, the introduction of indigo and logwood met with legislative opposition. In England these valuable drugs were prohibited by act of parliament, and ordered to be destroyed wherever found.

In the early part of the fourteenth century, Florence became the head-quarters of the tinctorial art, counting no fewer than two hundred dye-works. The extraction of archil from lichens was learned by a native of this city in Syria, and introduced into Italy.

In 1560, compounds of tin were first introduced as mordants —a capital improvement. The invention is generally ascribed to Cornelius Drebbel, a Dutchman, one of whose descendants founded extensive dye-works at Bow, near London.

Calico printing, though practised in India from time immemorial, and in Asia Minor during the middle ages, did not penetrate into England until near the close of the seventeenth century.

Textile manufactures were still in a very rude state. The culture and manufacture of silk had flourished under the Moors in Spain, at a very early period. It was introduced into France in 1521, and into England at the end of the sixteenth century. In 1629, the silk-weavers of London were formed into a corporation.

The manufactures of wool and linen existed very early in England, but only on a small scale. Not until mechanical power was called in to supersede human labour, do the textile manufactures of England give any indication of their modern importance.

A circumstance which cannot fail to attract our attention, is the very recent date of those great branches of industry which constitute so conspicuous an element of our national greatness. They are, so to speak, introductions of yesterday.

The chief sources of motive power in this epoch were still the muscular force of men and animals. Water and wind were used for grinding corn, and a few other similar operations. No traces of the steam engine appear in this epoch.

With this survey of the practical arts, rendered somewhat meagre by the spirit of concealment still dominant in the workshop, we close our survey of the pre-Baconian epoch.

It is easy to see that, notwithstanding the scholastic philosophy still reigned in all the seats of learning, a revolution, or rather a new phase of development, was at hand. Not merely had prevalent views been openly and boldly called in question by eminent thinkers, but, what is perhaps still more significant, a vast mass of knowledge had been gradually accumulating, which would not amalgamate with the scholastic system, which pointed to new methods and new objects. As a necessary result it was an age of expectation. Every clear-sighted and observant man would naturally be struck with these facts, and seek to interpret and organize them. One mighty thinker at last apprehended clearly and fully, what to the many had "loomed at a distance," and what he thus apprehended he uttered in language so impressive, that the world at once listened and obeyed. That thinker was the father of modern philosophy—Francis Bacon.

CONCHOLOGY.

CHAPTER X.

ORDER II.—DIMAYRIA.

Shells with two distinct, remote, muscular impressions, which are widely separated, and inserted towards the lateral extremities of the valves.

GRAND DIVISION I.
Shells irregular, and always inequivalve.

TRIBE I.—CHAMACEA.

Shell inequivalve, irregular, attached to other bodies; hinge with one or more large teeth, and provided with two separate lateral muscular impressions.

Genus.—CHAMA.—*Bruguière.*

Generic Character.—Shell irregular, thick, usually very inequivalve, for the most part covered with irregular spines, or foliated processes; umbones distorted, unequal, distant, and involute; that of the attached valve salient at the base, and in some instances projecting considerably beyond it, the other is for the most part reflected over upon its valve, appearing as if imbedded in it; hinge with one strong, thick, irregular, oblique, striated, and generally crenated tooth in one valve, which fits into an irregular striated groove in the opposite valve; each valve provided with two distant, lateral, muscular impressions; line of the mantle attachment entire; ligament external, subdivided at its posterior extremity; one of the segments decurrent to the point of the umbo in each valve.

Chama Haliotoidea. Plate VIII. fig. 15. *C. Ponderosa.* Plate VIII. figs. 9, 10.

The Chamæ are distinguished from the shells of the genus *Diceras*, by the latter having large, conical, divergent, spiral, horn-shaped umbones, and in its larger valve having a large, subauriculate, concave, and prominent tooth; *Isocardia* is more regular in form; *Spondylus* will be distinguished by its triangular area between the umbones; and although the *Cleidotheras* has some resemblance to a Chama, it is provided with a separate bony appendage; the hinge, and its elongated muscular impressions, will serve farther to distinguish it.

There are numerous fossil Chamæ, which are found in the Calcaire-grossier, Greensand, and London Clay.

Genus.—DICERAS.—*Lamarck.*

Generic Character.—Shell inequivalve, inequilateral, the one valve larger than the other; attached to extraneous substances by the point of the beak of the larger valve, which is provided with one very large, concave, somewhat auriform and thick cardinal tooth; each valve furnished with two lateral, remote, muscular impressions; umbones large, very prominent, divaricated, and somewhat irregularly and spirally twisted.

The united valves of this shell present the appearance of ram's horns.

Diceras acutus. Plate VIII. fig. 20. *D. Lonsdalii.* Plate VIII. figs. 18, 19.

Only two species of this genus are known; they are fossils; the former found in the Granular Limestone of Normandy, and in the neighbourhood of Geneva; the latter in the Greensand of North Wiltshire.

GRAND DIVISION II.—LAMELLIPEDES.

The foot of the animal depressed, lamelliform, and not posterior.

TRIBE I.—NAYADES.

Shells inhabiting fresh waters. Hinge sometimes provided with an irregular, simple, or divided tooth, and a longitudinal prolonged one; sometimes toothless; some have irregular granulated tubercles, extending the whole length of the hinge line; provided with a compound muscular impression; the umbones frequently decorticated.

Genus.—ANODONTA.—*Bruguière.*

Generic Character.—Shell equivalve, inequilateral, and transverse, for the most part very thin; hinge line nearly straight; destitute of cardinal teeth; the hinge being glabrous with smooth laminæ, truncated, or forming a sinus at the anterior end, terminating the apex of the shell; two lateral remote muscular impressions, the posterior one being compound; muscular impressions of the mantle entire, and seldom distinctly marked; ligament linear, external, sunk in a cleft at the anterior extremity.

Anodonta Cordierii. Plate VIII. fig. 2. Found in the Calcaire-grossier at Paris.

The shells of this genus are fluviatile, inhabiting lakes, rivers, and canals in all countries, but they are chiefly found in still waters, adhering to the mud at the bottom, generally a little sunk into it. They are at once distinguished from their congenerous genera, Hyria, Unio, Iridina, and Megadesma, by being totally devoid of teeth.

Fossil Anodontæ are very rare.

Genus.—UNIO.—*Retzius.*

Generic Character.—Shell transverse, equivalve, inequilateral, free, sometimes subcordate, or suborbicular; pearlaceous within; generally covered with a dark olivaceous epidermis, which is usually decorticated on the umbones, which are prominent; hinge provided with a short, irregular, simple, or a double compound tooth, which is almost always striated; with two elongated, compressed, lateral teeth, the front one produced, sometimes obsolete; two muscular impressions in each valve, the superior one compound, or composed of several divisions; ligament external.

Unio subtruncatus. Plate VIII. fig. 22.

The teeth vary considerably in their progress from the young to the adult condition.

Fossil species are numerous.

The species of this genus are very numerous, inhabiting lakes, rivers, and canals in almost every quarter of the globe. The great rivers of America are very rich in species. They vary considerably in their external form, being sometimes nearly cordate; for the most part thick, and oftentimes very ponderous for their size.

TRIBE II.—TRIGONACEA.

Primary teeth lamelliform, and transversely striated.

Genus.—TRIGONIA.—*Bruguière.*

Generic Character.—Shell equivalve, inequilateral, transverse, trigonal, sometimes suborbicular; cardinal teeth oblong, laterally compressed, divergent, two in the right valve transversely grooved on both sides; the grooves regularly marked, each forming the segment of a circle; four teeth in the left valve grooved in one side only, but these alternately in pairs; consequently the four teeth of this valve receive within their grooved sides the two teeth of the right valve; two principal muscular impressions, the lateral ones very distinct, one of which is situate close to the superior end of the cardinal tooth, and a little behind it; the other somewhat more distant, with a minute one between it and the cardinal tooth; mantle muscular impressions almost entire; ligament marginal, thick, rather short, and external.

Trigonia costata. Plate VIII. fig. 24. *T. politus.* Plate VIII. fig. 25.

Only one recent species of this genus is known, which inhabits the seas of New Holland. Many fossil species are found in the Lias, the upper and lower Oolites, and Greensand, and characterize the strata above the Lias and below the Chalk.

TRIBE III.—ARCACEA.

Shells provided with numerous small primary teeth, disposed in a straight or interrupted line in each valve.

Genus.—NUCULA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, transverse, oval, trigonal, or oblong; generally covered with an epidermis; hinge linear, narrow, divided into two parts by an oblique, produced, nearly central pit, which is destined for the reception of the ligament, the one anterior, and the other posterior; lateral teeth on each side numerous, acute, elevated, somewhat recurved, those of the opposite valves locking into the intervening spaces; umbones contiguous, and not separated by an intervening area; two simple muscular impressions; mantle impression destitute of a sinus.

Nucula Cobboldiæ. Plate VIII. fig. 29.

Genus.—LEDA.—*Schumacher.*

Generic Character.—Shell equivalve, inequilateral, elliptical or fig-shaped, more or less angulated or acuminated posteriorly; smooth or transversely striated, covered by an epidermis in the recent condition; umbones small and approximating; hinge

furnished with numerous teeth arranged in a linear series, curved or slightly angular, interrupted in the centre, or immediately beneath the beaks, by a triangular fossette for the reception of the ligament; muscular impressions ovate or subtriangular; pallial impression more or less sinuated.

Leda semistriata. Plate VIII. fig. 38.

The shells of this genus are found in the Coralline Crag, the Mammiferous Crag, and Red Crag.

Genus.—Nucinella.—*S. Wood.*

Generic Character.—Shell equivalve, inequilateral, closed, ovate, or subtrigonal, anterior side short, truncate; posterior produced, ovate or subangular; hinge line broad, slightly curved, and furnished with teeth; one large lateral tooth in the posterior side.

Nucinella miliaris. Plate VIII. fig. 30.

One species only is known, and which is found in the Paris Basin at Grignon, and the Coral Crag, Ramshot, and Sutton.

Genus.—Limopsis.—*Sassi.*

Generic Character.—Shell orbicular, or obliquely ovate, convex, or lenticular, equivalved, subequilateral, and closed; hinge composed of numerous teeth, arranged in a more or less curvilinear direction, projecting and interlocking; umbones distant; cardinal area large and external, divided by a triangular fossette situate immediately beneath the umbo; pallial impression entire, or without a sinus; impressions of the adductor muscle subovate and deeply impressed.

Limopsis aurita. Plate VIII. fig. 28.

These shells are found in the Coral Crag at Sutton and Gedgrave.

The shells of this genus are marine. Many fossil species have been discovered; they occur in the Crag, London Clay, and Chalk Marl of England, France, and Italy; especially in the Calcaire-grossier of Bordeaux, Volognes, and Paris; and also in our British Greensand.

In the species *N. lanceolata*, *fluviatilis*, *pella*, *rostrata*, *tellinoides*, and *oblonga*, there is a small sinus in the muscular impression of the mantle.

Genus.—Myopara.—*Lea.*

Generic Character.—Shell inequivalve, inequilateral, subtransverse; beaks elongated and incurved; teeth numerous, placed in a divergent, interrupted series on each side of the pits, formed for the reception of the ligament; margins of valves smooth.

Myopara costatus. Plate VIII. fig. 14.

Known only in a fossil condition, in the United States of America.

Genus.—Pectunculus.—*Lamarck.*

Generic Character.—Shell orbicular, subequilateral, with the valves close; umbones near to each other, and separated by a narrow facet, or area; hinge semicircular; teeth numerous, arcuated, oblique, serrated, placed in two rows, one on each side of the umbones, and are separated by a small triangular disk in each valve, which contains the ligament, those of the opposite valves alternately inserted between each other, and becoming nearly obsolete towards the umbones; two lateral, strongly marked, distant, muscular impressions, which are united by an uninterrupted pallial impression; ligament external.

Pectunculus Plumstedensis. Plate VIII. fig. 26.

The well-marked characters of this genus will distinguish it from all others.

The Pectunculi are covered with a pileous epidermis; they inhabit the ocean, occupying a wide geographical range, being met with in almost all countries. Fossil species occur in the Calcaire-grossier and London Clay, and are numerous in the Crag.

Genus.—Arca.—*Linnæus.*

Generic Character.—Shell transverse, or subequivalve, inequilateral, trapeziform, or subquadrate; slightly ventricose; some are greatly ventricose; generally angular at both ends of the hinge line, much rounded in some species; umbones small, remote, separated by the area to which the external ligament is affixed; hinge line rectilinear; teeth numerous, small, serrated, close-set, alternately inserted in the opposite valves; two lateral and distant muscular impressions, ligament external.

Arca appendiculata. Plate VIII. fig. 34.

The Arcæ are marine shells, inhabiting the coasts of all climates, and bury themselves in the sand, in the same manner as the Cardiæ. Several species, such as the *Arca Noæ*, and its congeners, are affixed to extraneous substances by a strong tendinous byssus; such species having an open space or commissure between the front part of the valves for its passage. This section has been formed into a distinct genus under the name of Bysso-arca.

Fossil Arcæ occur numerously in the Tertiary deposits, and some few are found in the inferior Oolite.

Genus.—Macrodon.—*Lycett.*

Generic Character.—Shell transverse, equivalve, inequilateral, subquadrate, somewhat ventricose; hinge line nearly parallel; umbones small, placed near to one end; remote and separated from each other by an area; hinge with six obliquely-parallel, linear teeth in the right valve, situated near the anterior extremity, the innermost tooth stretching transversely the entire length of the hinge line; these teeth are received into corresponding cavities formed for their reception in the opposite valve; base or ventral margin provided with a hiatus for the passage of the byssus, and producing a corrugation in the edge of the valves: two muscular impressions in each valve, the anterior one furnished with a prominent ledge, projecting from the side of the shell, the posterior one expanded and indistinct.

Macrodon rugosus. Plate VIII. fig. 21.

Only one species of this genus has been discovered in the Oolite, at the top of Leckhampton and Crickley Hills, and near Minchenhampton.

Genus.—Cucullæ.—*Lamarck.*

Generic Character.—Shell subequivalve, trapeziform, or subquadrate, very ventricose; beaks distant, separated by a flat external area, on which the ligament is placed; two muscular impressions in each valve, of which the anterior one is elevated into a sharp-edged plate or ledge projecting from the side of the shell; margin angulated, or with an ear-produced border; hinge rectilinear, or with a series of angular, somewhat irregular teeth, set transversely, very small near the umbones, longer and more oblique towards both extremities; covered by an epidermis.

Cucullæa glabra. Plate VIII. fig. 23.

A small portion of the anterior side of the area remains uncovered by the ligament; the area increases in size by age, and is transversely grooved in the adult state: an obtuse angle renders the anterior portions of the shells distinct, and when the valves are shut, and that side alone presented to view, it is cordiform and longitudinally produced in the centre. The larger valve is more intensely coloured, with stronger markings inside; the smaller one being paler in colour, with more distinct and closer set striæ than the opposite valve.

Only one recent species of Cucullæa is known; it inhabits the ocean. Several fossil species have been found in the Greensand and in the inferior Oolite of Britain, and at Grignon, Bordeaux, and Beauvais, France.

Genus.—Axinus.—*Sowerby.*

Generic Character.—Shell equivalve, transverse free, posterior side very short, rounded; hinge provided with a long, oblique ligament, situate in a furrow, stretching along the whole edge; anterior side considerably produced, angulated, and somewhat obliquely truncated, with a flattish lunette near the beaks.

Axinus obscurus. Plate VIII. fig. 21.

Known only in a fossil state. Found in the Magnesian Marl at Colyhurst, near Manchester, and at Garforth Cliff, near Leeds.

TRIBE IV.—CARDIACEA.

Primary teeth irregular both in form and situation, and in general accompanied by one or two lateral teeth.

Genus.—PACHYMA.—*Sowerby.*

Generic Character.—Shell very thick, equivalve, transversely elongated; sublobate, with the umbones situate near the anterior extremity; ligament short, partly internal, and attached to a prominent process, or fulcrum; close at both extremities.

Pachymya gigas. Plate VIII. figs. 27 and 35.

This singular bivalve has considerably the aspect of a *Modiola*, but differs from that genus in the ligament being attached to a prominent fulcrum: the position of the umbones, the elongate shape, and partial separation of the anterior portion into a sublobate form, all connect it with Modiola, but the position and manner of attachment of the ligament bring it near *Cypricardia*, but it is distinguished from the latter genus by its great thickness, depth, and oblique ridge which crosses the valves.

Known only in a fossil condition, and is found in the lower portion of the Chalk at Lyme-Regis.

Genus.—HIPPOPODIUM.—*Conybeare.*

Generic Character.—Shell equivalve, obliquely transverse, very thick, deep, and inequilateral; umbones incurved; ventral margin sinuated so as to produce a bilobate appearance; hinge much thickened, and furnished with one rugged oblique tooth.

Hippopodium ponderosum. Plate VIII. figs. 31, 39.

Found in a fossil state only. It occurs in the upper beds of the Lias.

Genus.—HIPPAGUS.—*Lea.*

Generic Character.—Shell equivalve, elongated, cordiform, ventricose, with incurved beaks: destitute of cardinal teeth.

Hippagus Isocardioides. Plate VIII. fig. 16.

Known only in a fossil state.

Genus.—MEGALODON.—*Sowerby.*

Generic Character.—Shell bivalve, equivalve, longitudinal, acuminated towards the beaks; a large bifid tooth placed upon a septum across the beak of the right valve, and one irregular and more acute tooth, similarly situate in the left valve; a small pit near the teeth for the reception of the ligament, which is anterior, long and external.

Megalodon cuculatus. Plate VIII. fig. 7.

This genus is nearly allied to Mytilus, but is at once distinguished by the large teeth at the hinge, and its ponderous valves. It has also some relation to Myochoncha, but the only muscular impressions which are visible, from their situation, more nearly connect it with the Mytili.

Known only in a fossil condition, and found in the Limestone at Bradley, near Newton Bushel, Devonshire.

Genus.—ISOCARDIA.—*Lamarck.*

Generic Character.—Shell equivalve, heart-shaped, ventricose; beaks very distant, divergent, and involute; hinge with two primary compressed teeth in each valve, the one next the apex inflected under the umbo; and with one elongated lateral tooth, situate immediately before the ligament, which is external, and divided into two ligaments at its posterior extremity, both of which are divergent to the point of the beak in each valve; both valves provided with two lateral, remote, muscular impressions, the linear impression of the mantle is entire, and extending from one muscular impression to the other.

Isocardia minima. Plate VIII. fig. 33.

The Isocardiæ are distinguished from the shells of the genera *Chama* and *Diceras*, by being equivalve, and in the ligament being dichotomous, and extending to the point of the umbo.

The Isocardiæa are oceanic shells, and the recent species are few. Fossil species occur in the Kelloways rock, the Crag and London Clay: and in a yellow-coloured Limestone at Coutances in France.

Genus.—CYPRICARDIA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, subquadrate, obliquely or transversely elongated; posterior side very short; hinge with three teeth in each valve, situate immediately within and behind the umbo; and one rather lengthened lateral tooth, extending towards the anterior side; each valve with two somewhat irregular, lateral, muscular impressions; mantle or pallial impression very indistinct and nearly obsolete; ligament external.

Cypricardia carinata. Plate VIII. fig. 32.

The Cypricardiæ inhabit the ocean, and are distinguished from the Carditæ, which they resemble very nearly in form, by having *three* cardinal teeth situate under the beaks. It is supposed that they affix themselves to marine bodies by a byssus.

Fossil species occur in the Blue Marls, south of France, and in the Silurian rocks of Britain.

Genus.—CARDITA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, suborbicular, subquadrate, transversely oblong, in some instances; more or less grooved exteriorly, emanating from the umbo, and terminating in the margin: lips crenulated interiorly; two generally oblique teeth in the left valve, one of which is elongated, thick, and for the most part curved; and in the right valve one elongated, thick, and oblique tooth, with a deep, lengthened cavity for the reception of the large tooth of the opposite valve; in some species there is an additional indistinct tooth in this valve; two somewhat ovate lateral muscular impressions in each valve; mantle muscular impression entire; ligament external.

Cardita lunulata. Plate VIII. figs. 36, 37.

Distinguished from the Cypricardiæ by the number of cardinal teeth; and although closely allied to Cardium, the shells of that genus are nearly equivalve, and besides having two cardinal teeth, there are remote lateral teeth on each side of the beaks.

The Carditæ inhabit the ocean, and fossil species are met with in the newer beds above the Chalk, the Crag, Calcaire-grossier, and London Clay.

Genus.—CARDIOMORPHA.—*De Koninck.*

Generic Character.—Shell equivalve, inequilateral, thin, generally oblique or transversely elongated; hinge linear, without teeth, cardinal plates smooth; prolonged from the umbones to the extremity of the cardinal margin; ligament linear, external; umbones recurved; muscular impressions two, joined by a simple pallial line.

Type *Cardiomorpha elongata,* De Koninck.

Genus.—PLEUROPHORUS.—*King.*

Generic Character.—Form inequilateral; cartilage external; anterior adductor muscular impressions deeply excavated, often bounded posteriorly by a ridge; pallial line entire; dentition cardinal and posterior; cardinal teeth, two in each valve, diverging inwardly, and interlocking alternately; posterior teeth linear; the receiving teeth in the left valve.

Type *Pleurophorus Costatus,* Brown. Trans. Manchester Geo. Soc. Plate VI. figs. 34, 35.

Found in the Magnesian Marl at Colyhurst, Manchester.

Genus.—OPIS.—*Defrance.*

Generic Character.—Shell equivalve, rhomboidal, heart-shaped, inflated; beaks involute and approximate, nearly touching; hinge area oblique; hinge with a large striated tooth, fitting into a socket in the opposite valve; lunette very large, deep, oval, and pointed below the cavity, which has two smaller teeth on each side.

Opis limulata. Brown's Fossil Conchology. Plate LXXX. figs. 15, 16.

Found in the inferior Oolite at Dundry, &c.

Genus.—CARDIUM.—*Linnæus.*

Generic Character.—Shell equivalve, nearly equilateral, and more or less gaping posteriorly; generally with strong ribs radiating from the umbones to the margins; inside of the lips crenulated or dentated, corresponding in size to the ribs; two approximate oblique cardinal teeth in both valves, locking into each other crossways; and with two remote lateral teeth in both valves; two lateral distinct muscular impressions in each valve; mantle impressions entire; ligament external.

Cardium Parkinsoni. Plate IX. fig. 30.

For the most part there is a slight difference in the form of the two valves of the Cardiæ, and in some few instances the external surface is smooth and destitute of ribs, but they have invariably a toothed or crenulated internal margin, the crenulations being always small in the smooth species. Although a very natural genus, there is nevertheless considerable variety in external form: the *C. tuberculatum* is almost globular; some are considerably longitudinal, as *C. soleniforme*, and others are deeper than wide, as *C. biradiatum*, and the *C. cardissa* has its sides considerably compressed.

The Cardiæ inhabit the ocean, generally lurking in the sand near low water-mark. Fossil species are met with in nearly almost the whole fossiliferous series, from the Mountain Limestone upwards; and are very numerous in the newer formations, such as the English Crag, London Clay, and Greensand.

Genus.—Pleurorhynchus.—*Phillips.*

Generic Character.—Shell transversely elongated; hinge line long, rectilinear; anterior side with a short prolongation; posterior side lengthened into an acute, wing-shaped, auricular process; generally longitudinally ribbed; beaks but slightly produced.

Pleurorhynchus Hibernica. Plate IX. fig. 32.

Found only in a fossil state in the Mountain Limestone.

We have instituted this genus for the reception of several remarkable fossils, which are met with in the Mountain Limestone. The type of the genus is the *Cardium Hibernicum* of Sowerby.

Genus.—Cardiola.—*Broderip.*

Generic Character.—Shell equivalve, oblique, inequilateral; beaks prominent and curved; surface concentrically furrowed; hinge line long, with a flat area.

Cardiola fibrosa. Plate IX. fig. 33.

The shells of this genus are highly characteristic of the lower members of the upper Silurian Rock, and are spread over a whole extent of country.

No recent species have been met with.

Genus.—Myoconcha.—*Sowerby.*

Generic Character.—Bivalve, equivalve, oblique, sides very unequal; hinge with an elongated oblique tooth in the left valve, and provided with an external ligament; beaks placed close to the posterior extremity; destitute of a sinus in the impression of the mantle.

Myoconcha crassa. Plate X. fig. 37.

In its general contour this shell resembles those of Modiola; and in the form of the hinge is somewhat allied to the genus Crassina, and to the Conchæ generally; but is, however, destitute of lateral teeth, and deficient in the posterior lobe; the posterior muscular impression is strongly indented. There is but one species known, and it occurs in a fossil state at Dundry, near Bristol.

TRIBE V.—CONCHACEA.

Shell with three primary teeth at least in one valve, and the other generally with the same number, but in some instances fewer.

SUBDIVISION I.—MARINE.—Generally destitute of lateral teeth.

Genus.—Venericardia.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, suborbicular, the surface generally with longitudinal radiating ribs or furrows; two oblique primary teeth, directed to the same side.

Venericardia planicosta. Plate IX. fig. 19.

Found fossil in the London Clay, Hampshire. It is also met with in the neighbourhood of Paris, at Piedmont, and Florence. Several other species occur in the London Clay and Crag of England, as also in the Supercretaceous rocks of Dax and Bordeaux.

The Venericardiæ are marine shells; one recent species only is known, which is peculiar to the seas of New Holland.

Genus.—Tapes.—*Megorle.*

Generic Character.—Shell equivalve, transverse, inequilateral, the anterior side being the shorter; three diverging cardinal teeth in both valves, situate near to each other, and generally with a notched or cleft termination; and in a few species the central tooth is deeply so; two lateral somewhat rounded muscular impressions in each valve; mantle muscular impression with a large sinus; ligament external, and partly concealed by the dorsal margins of the valves.

Pullastra recondita. Plate X. fig. 12. *P. globosa.* Plate X. figs. 25, 35.

This genus was established by Sowerby for the reception of Lamarck's *Venus Pullastra*, *Virginea decussata*, and their congenerous species, to which he has most properly united the whole of the species forming Lamarck's genus *Venerupis*, whose characters entirely agree with the Veneres; and the animals are also of the same natural genus.

The Tapesidæ are marine shells. They occur in a fossil state, and are only found in the Tertiary formations.

Genus.—Venus.—*Linnæus.*

Generic Character.—Shell smooth, equivalve, inequilateral, transverse, subglobose or suboval; external surface sometimes rugose, margin close; three divergent cardinal teeth in each valve, all approximate; umbones prominent for the most part, with a cordiform depression immediately below them; two lateral, remote, somewhat orbicular muscular impressions, united by a pallial impression, which is generally sinuated behind; ligament external, although sometimes almost hidden by the extension of the outer edge of the shell.

Venus incrassata. Plate IX. fig. 13.

This extensive genus requires to be divided into the following sections:—

SUBDIVISION I.—Lunule distinctly circumscribed by an impressed line.

Section 1. Somewhat cordiform, generally a little acuminated and rounded anteriorly; sinus of the pallial impression nearly obsolete; each valve with two large distinct divergent teeth, and a small tooth, which is anterior in the right valve, and posterior in the left; as in *V. Paphia.*

Section 2. Subovate, anterior side considerably shorter than the posterior; generally lamellose or longitudinally grooved externally; each valve with three strong divergent cardinal teeth, the two anterior ones emarginate in one valve, and the two posterior ones in the other, with a moderately-sized siphonal impression, and a little rounded. *V. purpurata* illustrates this section.

Section 3. Like those of section 2, but with external, thin, remote lamellæ; pallial impression anteriorly acuminated and very small; central cardinal teeth large and thick; the others small and thin; the anterior somewhat curved, as exemplified in *V. lamellosa.*

Section 4. Exteriorly rough, and cancellated; the central and posterior teeth in the right valve large, thick, and emarginate, the anterior linear and thin; in the left valve the central tooth is thick and emarginate, while the anterior is elongated, thick, and linear; posterior tooth small, linear, thin, and nearly obsolete; pallial sinus rounded in front, and of moderate size.

Section 5. In the right valve the posterior teeth are very large and thick, and the two anterior teeth small and contiguous, the intervening space only fitted to receive the thin lamellar anterior tooth of the left valve; central tooth of the left valve thick and double, and the posterior elongated and narrow, somewhat lamellose, muricated or externally cancellated; siphonal impression large and acuminated.

SUBDIVISION II.—Lunule not circumscribed by an impressed line.

Section 6. External form nearly orbicular; three divergent teeth in the hinge; pallial sinus large and acute at its anterior end, with a flattened space under the fulcrum, to which the ligament is attached: surface almost smooth.

Section 7. External form ovate and very thin; right valve, with the two anterior teeth, thin, lamellar, and contiguous, the intervening cavity receiving a thin tooth of the opposite valve, the posterior tooth double, thin, and elongated; left valve with a thick and large central tooth, and having a very thin and linear posterior tooth; siphonal impression large.

Section 8. External form approaching the Cytheræ, surface smooth; pallial impression with a small rounded sinus; right valve with three teeth, the posterior two large, and the anterior very small; left valve with three large teeth.

The Veneres are marine shells, inhabiting the shores of almost all countries, and bury themselves in the sand.

Fossil shells of this genus are found in the beds of the Tertiary formations.

Genus.—CYTHEREA.—*Lamarck.*

Generic Character.—Shell bivalve, equivalve, generally more or less equilateral, or obtusely trigonal and transverse, or ovate; smooth, or variously striated; with three or more short divergent cardinal teeth, and one anterior approximate lateral tooth in both valves, situate near the primary teeth; two remote, lateral muscular impressions, united by a pallial impression; ligament external.

Cytherea polita. Plate X. fig. 10.

The shells of this genus are distinguished from those of Venus by their lateral teeth.

This comprehensive genus may be properly separated into the following sections:—

Section 1. Agreeing in general character with the shells of the genus *Venus*, the only difference being in the species of this section having a distinct, blunted, lateral tooth, and in the pallial impression being destitute of a sinus; most of the species are smooth on the external surface; some few have divergent striæ and ribs; and others are concentrically striated, with their beaks inclined forwards; lunule more distinctly marked than in their congeners. *C. scripta* and *ornata*, &c., illustrate this section.

Section 2. External surface smooth, and provided with a thin corneous epidermis; three divergent cardinal teeth in each valve, and a lateral anterior tooth situate under the elongated and indistinct lunule; muscular impression of the mantle provided with a small sinus; general shape obtusely trigonal; anterior side shortest; umbones with a slight inclination forwards. *C. lusoria* and *petechialis* illustrate this section.

This may be considered the typical group of the Cythereæ.

Section 3. External surface smooth and covered by a thin velvety epidermis; four or five divergent cardinal teeth; an elongated, nearly lamellar anterior lateral tooth; muscular impression of the mantle, with a large rounded sinus; lunule elongated and indistinct; beaks less inclined forwards than in the preceding section. Illustrated by *C. corbis.*

Section 4. External form nearly oval, anterior side much shorter than the posterior; outside smooth, and covered by a thin corneous epidermis; a few, however, are grooved longitudinally; three divergent cardinal teeth in each valve, and a closely approximated, blunted lateral tooth; pallial impression very large, and usually pointed at its anterior end. *C. erycina* and *chione* are examples of this group.

We have removed those shells of a lenticular form, such as *C. exoleta* and its congeners, and constituted a new genus with them, under the title of *Artemis.* This genus was instituted by Poli.

The Cythereæ inhabit the ocean; and are distinguished from the Veneres and the Cyprinæ, by having a lateral tooth; and from the Lucinæ, by the form of the muscular impression.

Fossil shells of this genus are principally met with in the Tertiary formations, the London Clay, Calcaire-grossier, and Greensand; and several species occur in the Oolitic group of rocks.

Genus.—ARTEMIS.—*Poli.*

Generic Character.—Shell nearly lenticular, externally and concentrically grooved; beaks much turned to one side, beneath which is a short, strongly-marked cordiform depression; three cardinal teeth in each valve, two of which are contiguous, and the other divergent, which is broad in the right valve, cleft in the centre, to receive that of the opposite valve, which is slender, with a small lateral and closely approximated tooth; pallial impression with a large oblique and straight-sided sinus; cartilage external.

Artemis lentiformis. Plate X. fig. 11.

The shells of this genus are marine, and live in deep water. Fossil species are rare, and occur in the Crag of Essex and Sussex.

Genus.—CYPRINA.—*Lamarck.*

Generic Character.—Shell ventricose, equivalve, inequilateral, suborbicular, obliquely heart-shaped; umbones obliquely curved anteriorly; three cardinal teeth in each valve, approximated at their bases, and divergent above, with a posterior lateral tooth remote from the primary teeth; external surface covered by a thick, rough, dark, horny epidermis; each valve with two lateral, remote, muscular impressions; pallial impression with a slight sinus; ligament external, inserted into a deep, marginal, posterior, dorsal sinus.

Cyprina equalis. Plate X. fig. 13.

The Cyprinæ are marine shells; three species only are known, and they inhabit the Northern hemisphere. Several fossil species occur in the Tertiary formations.

They may at once be distinguished from the Venus and Cytherea by their thick epidermis, and remote lateral teeth.

SUBDIVISION II.—FLUVIATILE.— Shells covered with a spurious epidermis, and the hinge provided with lateral teeth.

Genus.—CYRENA.—*Lamarck.*

Generic Character.—Shell suborbicular, subtrigonal, equivalve, ventricose, inequilateral, and solid; external surface covered with a strong epidermis, and the umbones usually decorticated; three cardinal and two remote lateral teeth in each valve; in one valve the posterior one is situate near the primary teeth, the anterior one being more remote, and placed before the ligament; in the opposite valve a deep groove intervenes between two teeth, one of which is large, and the other nearly obsolete; two lateral remote muscular impressions; pallial impression destitute of a sinus; ligament external.

Cyrena cuneiformis. Plate X. fig. 2.

This genus is divided into two sections.

Section 1. With the lateral teeth crenulated, striated, or serrated.

Section 2. Lateral teeth entire, and destitute of striæ, or crenulations.

The species of this genus have a considerable similitude to those of *Venus*, *Cyprina*, *Cytherea*, and *Cyclas.* From the former three they are distinguished by their two remote lateral teeth, and by the thickness of their shell from *Cyclas.*

The Cyrenæ are all fluviatile shells, and entirely inhabitants of tropical climates. They occur abundantly in a fossil state in the upper Marine formation of the Isle of Wight, at Woolwich, Hordwell, and neighbourhood of Paris.

Genus.—CYCLAS.—*Bruguière.*

Generic Character.—Shell generally suborbicular, ventricose, equivalve, nearly equilateral, transverse, and thin, covered with a delicate olivaceous epidermis; two very minute, divergent, cardinal teeth in both valves, one of which is double in the left one; two remote and a little elongated, laminar, compressed, and acute lateral teeth; and four in the other, two of which are very small, situate on each side of the hinge; two lateral ovate muscular impressions in each valve, that of the mantle entire, and destitute of a sinus; ligament external and slender.

Cyclas deperdita. Plate IX. fig. 12. *C. lævigata.* Plate X. fig. 20.

The Cyclades appear to be found only in the continents of Europe and America. They inhabit lakes, ponds, ditches, and slow running streams. Fossil species occur in the recent lacustrine formations, and the Blue Marls of France.

Genus.—PISCIDIUM.—*Pfeiffer.*

Generic Character.—Shell small, equivalve, inequilateral, subovate, more or less inflated, rather thin, in the recent state subpellucid, and covered with an epidermis; smooth or concentrically striated; hinge with one or two cardinal, and two lateral teeth in each valve; ligament external, situated on the shorter side; muscular and pallial impressions indistinct.

Piscidium amnicum. Plate IX. fig. 27.

Found in the Mammiferous Crag, &c.

GRAND DIVISION III.—TENUIPEDES.

The mantle barely united before; foot small, narrow, and compressed; shell having but a moderate gape.

TRIBE I.—NYMPHACEA.

Having never more than two primary teeth in the same valve; shell often gaping slightly at the lateral extremities; ligament external; umbones generally projecting outwards.

SUBDIVISION I.—Destitute of lateral teeth.

Genus.—Astarte.—*Sowerby.*

Generic Character.—Shell suborbicular, transverse, equivalve, inequilateral; hinge with two strong, divergent, cardinal teeth in the right valve, and two unequal primary teeth, and one small, nearly obsolete tooth, together with an indistinct lateral one in the left valve; two ovate or oblong, remote, lateral, simple muscular impressions in each valve, with a third very small one, situate immediately below the indistinct lateral tooth, or at the end of the posterior external depression, and in some instances mingling with the lower termination of the posterior muscular impression, which is always simple and not sinuated; ligament external.

Astarte lurida. Plate IX. fig. 6.

These are marine shells, and do not appear to be met with in the tropics. One species inhabits the Northern Ocean. They are distinguished from *Crassatella* by their external ligament.

Fossil species are numerous, and occur in the lower Oolite, the English Crag, and Greensand.

Genus.—Cardinia.—*Agassiz.*

Generic Character.—Shell transverse, elliptical, equivalve, inequilateral, thick; hinge very strong, with one oblique, thickened cardinal tooth in the right valve, with a pit for its reception in the left valve; anterior lateral tooth in the right valve obtusely conical; the posterior tooth in the left valve elongated, and attenuated towards the umbo; right valve with a flattened fold lying parallel to the ligament, and divided obliquely near the umbo by a faint groove; from the anterior extremity of this fold a depression extends beneath the lunule, in front of the anterior lateral tooth, with a corresponding elevation; umbones closely approximating; muscular impressions deep; pallial impressions entire, deeply defined, and destitute of a sinus; ligament external, situate in a deep, marginal, dorsal sinus.

Cardinia crassissima. Plate IX. fig. 17.

This is entirely a fossil genus, the species hitherto have been considered and described as belonging to the genus *Unio*, they occur in the Oolitic group, and in the Lias. The difference between Unio and Cardinia is, that the cardinal tooth is frequently obsolete, the anterior lateral tooth thick, simple, and destitute of striæ, is situated in the right valve, with a hollow for its reception in the left valve; the posterior lateral tooth is placed in the left valve, and the sulcus for its reception in the right; the two muscular cicatrices are very deep, with a small round impression above the anterior one in the left valve. They are also destitute of any erosion at the umbo, so common in fluviatile bivalves; and the lines of growth are very strongly marked.

SUBDIVISION II.—With one or two lateral teeth.

Genus.—Donax.—*Linnæus.*

Generic Character.—Shell transverse, trigonal, equivalve, inequilateral, outer surface generally covered with a thin horny epidermis, anterior side for the most part the shorter; left valve with two more or less distinct cardinal teeth; right valve with only one cardinal tooth, which is generally cleft at its extremity; lateral teeth variable, either two or one very minute and remote; muscular impression of the mantle with a large sinus; ligament external and short.

Donax retusa. Plate X. fig. 1.

In some there are two lateral teeth, one of which being placed on each side of and near to the primary teeth; one valve is provided with a linear posterior process, remotely situated from the other lateral teeth, and between which and the margin of the shell there is a groove for the reception of the teeth of the other valve; the anterior lateral tooth can alone be distinguished in each valve in other species, together with the linear process; in other species there are two lateral teeth in one valve, the posterior one more remote than the anterior, while in the opposite valve there are only slight indications of them; and in some species the lateral teeth are nearly obsolete. The ligament is generally short, and in some instances very much so, the greater portion of it is situate anteriorly; * but in most of the species a small portion of the ligament is likewise placed behind the beaks. The shells of this genus are for the most part wedge-shaped.

Some species of Erycinæ may be mistaken for Donaces, but the ligamentary pit in the hinge of the former genus will at once distinguish it from the latter; the Capsæ have also a strong resemblance to this genus, but are always devoid of the short anterior side, and crenated margins which characterize the Donaces.

The Donaces inhabit the ocean. Fossil species are few and rare. Brocchi mentions only two, and Sowerby one from Bordeaux.

Genus.—Trigonellites.—*Parkinson.*

Generic Character.—Shell slightly rounded, trigonal, thick, gaping on each side; anterior side nearly straight; posterior side gently waving; hinge-line quite linear, destitute of teeth, with an appropriate surface on the anterior margin of each valve, for the attachment of the cartilage externally; no visible muscular impressions; substance of the shell very thick.

Trigonellites latus. Brown's Foss. Conch., Plate LXXV. fig. 6.

Found in the Kimmeridge and Oxford Clay, Whitchurch, Southrey, &c.

Genus.—Lucina.—*Bruguière.*

Generic Character.—Shell equivalve, inequilateral, usually orbicular, lenticular, and subdepressed; teeth variable, most commonly two minute cardinal teeth, divergent from the umbo, frequently nearly obsolete; in one valve one lateral tooth on each side of the umbo, and two on each side in the other; the anterior lateral ones being situate near the primary teeth, and the posterior immediately behind the ligament; two muscular impressions remote from each other, the anterior one generally extruded backwards and downwards in the form of an elongated band; pallial impression destitute of a sinus; ligament external, elongated, and partly hidden by the inflected margins of the valves when closed; consequently, the internal tendinous portion is frequently sunk into a deep elongated cavity, situate between the teeth and hinge-margin.

Lucina mites. Plate X. fig. 7.

Although the general form of the Lucinæ is lenticular, they are subject to considerable variety; some species—the L. Columbella, for example, are nearly globular. The teeth also differ considerably in number and size, but never in position; some species have cardinal teeth only, while in others the lateral are more distinct than the cardinal teeth; in a few species both are considerably developed, and in others they are all nearly obsolete.

The Lucinæ have much of the general aspect of the Amphidesmæ, but are distinguished by their anterior muscular impression being ligulate; the Amphidesmæ have a very large sinus in the muscular impression of the mantle, and the tendinous part of the ligament entirely internal. This ligulate muscular impression distinguishes them from the Cythereæ.

The Lucinæ inhabit the ocean. Fossil species are numerous, and occur in the beds of the Tertiary formations, of which they are a characteristic type.

Genus.—Diplodonta.—*Brown.*

Generic Character.—Shell somewhat thin, more or less orbicular, equivalve, subequilateral, externally smooth, or slightly marked by lines of growth; umbones not very prominent; hinge with two cardinal teeth in each valve, the anterior one

* Contrary to Lamarck, we consider the side in which the ligament is situate to be the *anterior side*, and it would only lead to confusion to make an exception in this genus.

in the right valve simple, the other bifid, and the reverse in the left; no lateral teeth; ligament external; no lunule; impressions of the adductor muscle ovate; pallial impression without a sinus.

Diplodonta dilatatæ. Plate IX. fig. 7.

Found in the Coralline Crag, Sutton, and Gedgrave.

Genus.—LUCINOPSIS.—*Forbes & Hanley.*

Generic Character.—Shell thin, equivalve, more or less orbicular, slightly inequilateral, valves closed; surface smooth or concentrically striated, with the inner margin entire; muscular impressions suborbicular or oblong, nearly equal; pallial impression wide, deep, central, and obtuse; hinge provided with two diverging cardinal teeth, one of which is bifid in the right valve, and in the left three teeth, the central one bifid; ligament external and rather long; no lunule.

Lucinopsis lajonkairii. Plate IX. fig. 10.

Found in the Coral Crag, Ramshot, and Sutton, and also in the Red Crag at Sutton.

Genus.—MONTACUTA.—*Turton.*

Generic Character.—Shell equivalve, inequilateral, transversely oblong, or obliquely ovate, generally small and thin, surface smooth, or concentrically striated, and occasionally with a few radiating ridges; hinge with two diverging elongated teeth, more conspicuous in one valve than in the other; ligament internal, placed in a triangular fossette; pallial impression destitute of a sinus.

Montacuta Donacina. Plate IX. fig. 31.

Found in the Coral Crag at Sutton.

Genus.—KELLIA.—*Turton.*

Generic Character.—Shell generally small and thin, equivalve, subequilateral, orbicular, spheroidal, ovate, or roundedly-oblong; tumid or compressed; surface smooth, or exhibiting visible lines of growth; hinge with two, sometimes only one tooth in each valve, with a trigonal pit for the reception of the ligament, which is within the margin of the shell, though visible in some species when the valves are closed; adductor muscular impressions suborbicular, often distinct; pallial impression without a sinus.

Kellia rubra. Plate IX. fig. 22.

Found in the Coralline Crag, Sutton.

Genus.—LEPTON.—*Turton.*

Generic Character.—Shell equivalve, subequilateral, ovate or subtrigonal, thin and compressed; umbones more or less acute, and not prominent; surface elegantly ornamented; margin plain; hinge composed of two diverging teeth in each valve, between which is placed the ligament, which is wholly internal; pallial impression simple, or destitute of a sinus.

Lepton squamosum. Plate IX. fig. 8.

Found in the Coral Crag at Sutton, &c.

Genus.—CRYPTODON.—*Turton.*

Generic Character.—Shell equivalve, tumid, thin, subhyaline, the valves closed; hinge with a single obtuse, or somewhat obscure tooth in each valve; destitute of lateral teeth; ligament semi-internal, placed in a linear depression beneath the dorsal margin; adductor muscular impression indistinct; pallial impression destitute of a sinus.

Cryptodon sinuosum. Plate IX. fig. 15.

Found in the Coral Crag at Sutton.

Genus.—LORIPES.—*Poli.*

Generic Character.—Shell orbicular, subequilateral, lenticular; smooth or striated externally; hinge with one or two cardinal, and two lateral teeth, the latter sometimes obsolete; muscular impressions unequal, anterior one the longer; pallial impression without a sinus.

Loripes divaricata. Plate IX. fig. 26.

Found in the Red Crag at Sutton, and the Mammiferous Crag, Bramerton.

Genus.—HIPPAGUS.—*Isaac Lea.*

Generic Character.—Shell cordate, inflated, destitute of teeth; beaks large, recurved, margin slightly overwrapping beneath the beak; anterior cicatrix long, posterior cicatrix round.

Hippagus ventricordius. Plate IX. fig. 11.

Genus.—CORBIS.—*Cuvier.*

Generic Character.—Shell transverse, equivalve, free, oval, thick, extremely ventricose and subequilateral; umbones small and incurved, two cardinal and two lateral teeth in each valve, the posterior one placed nearer to the cardinal teeth than the other, which is rather remote from the umbones, and situate near the termination of the ligament; two lunulate muscular impressions in each valve, simple, somewhat oblong in form, and placed close behind the umbones; pallial impression entire, and destitute of a sinus; ligament external, the parts to which it adheres forming a deep groove when the valves are closed.

Corbis lævis. Plate IX. fig. 9.

The shells of this genus are somewhat allied to the Lucinæ, but may be distinguished by their more oval form, by the simple, rather oblong muscular impressions; they are also something like the Tellinæ, but are destitute of the fold of the anterior margin of that genus; some species of Cythereæ and Venus resemble Corbis, but the lateral teeth, and entire pallial impression, will at once distinguish them.

Only one recent species of this genus is known, which inhabits the Indian Ocean. Lamarck describes two species, from the newer formations above the Chalk at Grignon and Granville in France.

Genus.—TELLINA.—*Linnæus.*

Generic Character.—Shell compressed, transverse, subequivalve, inequilateral; posterior side usually rounded; the anterior somewhat produced, or beaked and angular; anterior ventral margin with an irregular flexuosity; generally with two cardinal teeth in each valve, but only one in some instances, usually two lateral teeth in both valves, but sometimes only one, and for the most part remote from the primaries; two distant muscular impressions; pallial impression with a very large sinus; ligament external.

Tellina patellares. Plate X. fig. 4. *T. ovata.* Plate IX. fig. 28.

Section 1. Shells transversely oblong; as in T. Spengleri and rostrata.

Section 2. Shells ovate, with a rough exterior, as exemplified in T. lingua felis.

Section 3. Shells nearly orbicular; as T. carnaria and scobinata.

Section 4. With one valve more flattened than the other, as in T. opercularis.

Section 5. Both valves remarkably convex, as in T. lacunosa.

The irregular fold in the anterior margin, is a striking characteristic of this genus.

The Tellinæ inhabit the sea, burrowing in the sand, generally on flat shores. The recent species are numerous, and but few have been found in a fossil state: these are peculiar to the newer Tertiary formations.

SUBDIVISION III.—SOLENAIRES.

Genus.—PSAMMOBIA.—*Lamarck.*

Generic Character.—Shell transverse, oblong, somewhat angular, gaping at each extremity, and covered with a thin horny epidermis; with two short, bifid, cardinal teeth in the left valve, and one in the right valve; two distant, suborbicular, muscular impressions in both valves, situate near each end of the valve; pallial impressions with a very large sinus; ligament external, and supported upon a prominent fulcrum.

Psammobia solida. Plate IX. fig. 2. *P. dubia.* Plate IX. fig. 21.

The Psammobiæ are marine shells, and inhabit the tropical as well as the temperate seas. They are distinguished from the Tellinæ by being destitute of the anterior marginal fold. Only a few species have been found in a fossil condition; in the Blue Marls of France, and in the Oolitic group of rocks.

The genus *Psammotæa* of Lamarck is suppressed, and its species united with those of this genus.

BOTANY.

CHAPTER XVIII.

CLASSIFICATION—DESCRIPTION OF PLATES.

FROM a sketch of the structure and physiology of plants, we have conducted the student to a point where he may be considered as ready to enter on a combination of all our observations; and now, after presenting him with a classification, we must leave him to pursue at large the history and character of vegetable races throughout the world. In the first place, as the groundwork of all arrangement, *classes* are formed, like nations, to stand at the top of a series, from possessing the most general and widely diffused resemblances. *Orders* again, like tribes, group together a number of subordinate characters in common. *Genus*, like a family, springs up from an assemblage of specific distinctions. A *species* consists of one individual of the same form, position, proportion, and general appearance of parts as another, deriving their origin from a successive generation; while *varieties* are merely the same individuals differently appareled. The artificial classification propounded by Linnæus, however imperfect, is entitled to notice, not only from the long celebrity it enjoyed, but from the purpose which it still serves as an index.

VIEW OF THE LINNÆAN CLASSES.

Flowers present or apparent. — Stamens and Pistil in every flower.

Disposition of the Sexual Organs.		Classes.	
Stamens of equal length, or not differing in certain proportions.			
Stamens free.	In number 1.	I. Monandria,	μόνος, *single*, and ἀνὴρ, *male* or *stamen*.
	" 2.	II. Diandria,	δὶς, *two*.
	" 3.	III. Triandria,	τρεῖς, *three*.
	" 4.	IV. Tetrandria,	τετρὰς, *four*.
	" 5.	V. Pentandria,	πέντει, *five*.
	" 6.	VI. Hexandria,	ἕξ, *six*.
	" 7.	VII. Heptandria,	ἑπτὰ, *seven*.
	" 8.	VIII. Octandria,	ὀκτὼ, *eight*.
	" 9.	IX. Enneandria,	ἐννέα, *nine*.
	" 10.	X. Decandria,	δέκα, *ten*.
	" 12–19.	XI. Dodecandria,	δώδεκα, *twelve*.
	" 20. Inserted on Calyx	XII. Icosandria,	εἴκοσι, *twenty*.
	Above 20. Inserted on Receptacle	XIII. Polyandria,	πολὺς, *many*.
Stamen of unequal length.			
	Two long and two short	XIV. Didynamia,	δύναμις, *superiority*.
	Four long and two short	XV. Tetradynamia,	" "
Stamens united.	By Filaments — In one fasciculus, or bundle	XVI. Monadelphia,	ἀδελφότης, *fraternity*.
	By Filaments — In two bundles	XVII. Diadelphia,	" "
	By Filaments — In bundles above two in number	XVIII. Polyadelphia,	" "
	By Anthers	XIX. Syngenesia,	σὺν, *together*, and γένεσις, *origin*.
	By Pistil on a column	XX. Gynandria,	γυνὴ, *female* or *pistil*.
Stamens and Pistil in different flowers.			
	On the same plant	XXI. Monœcia,	μόνος and οἶκος, *house*.
	On different plants	XXII. Diœcia,	δὶς and " "
	Stamens and Pistil in the same or different flowers, on the same or different plants	XXIII. Polygamia,	πολὺς and γάμος, *marriage*.
	Organ absent or concealed	XXIV. Cryptogamia,	κρυπτὸς, *concealed*, and γάμος, *marriage*.

THE LINNÆAN ORDERS AND GENERA

Are chiefly named from the pistil, or female part of a plant, which is usually reckoned from the base of the style, if there be any, and if that be wanting, it is fixed from the stigmata.

	Orders.			Examples of Genera.
I.	Monogynia,	μόνος and γυνὴ,	1. free style,	Ginger, turmeric, mare's tail.
II.	Digynia,	δὶς "	2. free styles,	Jessamine, privet, olive, lilac, speedwell.
III.	Trigynia,	τρεῖς "	3. " "	Valerian, tamarind, iris, and the grasses.
IV.	Tetragynia,	τετρὰς "	4. " "	Teazel, madder, holly, woodroof.
V.	Pentagynia,	πέντε "	5. " "	Bell-flower, bindweed, mullein, thorn-apple.
VI.	Hexagynia,	ἕξ "	6. " "	Snowdrop, narcissus, tulip, aloe, hyacinth.
VII.	Heptagynia,	ἑπτὰ "	7. " "	Horse-chestnut.
VIII.	Octagynia,	ὀκτὼ "	8. " "	Indian cress, heath, French willow.
IX.	Enneagynia,	ἐννέα "	9. " "	Bay, rhubarb.
X.	Decagynia,	δέκα "	10. " "	Rue, rhododendron.
XI.	Dodecagynia,	δώδεκα "	12. " "	Purslane, houseleek.
XII.	Polygynia,	πολὺς "	20. and upwards,	Peach, medlar, apple, rose, cinquefoil.
XIII.	Monogynia, Pentagynia, and Polygynia, as before,			Herb christopher, poppy, larkspur, columbine.
XIV.	Gymnospermia, γυμνὸς, *naked*, σπέρμα, *seed*,			Germander, savoy, hyssop, lavender, betony.
	Angiospermia, ἄγγος, *vessel*, " "			Eyebright, toothwort, lousewort, snapdragon.
XV.	Siliculosa; seeds contained in a short round pod,			Rose of Jericho, madwort, sea-rocket.
	Siliquosa; " " long slender pod,			Toothwort, wall cress, cabbage, radish.
XVI.	Triandria, Decandria, &c., as in the classes,			Tamarind, crane's bill, passion-flower.
XVII.				Fumitory, milk-wort, dogwood, lupine.
XVIII.				St. John's-wort, painter's golden apple.
XIX.	Polygamia,	Florets are hermaphrodite,		Old man's beard, oxtongue, lettuce, burdock.
		Florets of disc hermaphrodite; those of the ray pistilliferous,		Tansy, May-weed, fleabane.
		Florets of disc hermaphrodite; those of ray neuter,		Sunflower, centaury.
		Florets of disc staminiferous; those of ray pistilliferous,		Marigold, African ragwort.
		Each floret with a separate involucre,		Elephant's foot, globe-flower.
	Monogamia.	Anthers united; flowers not compound,		Sheep's scabious, balsam.
XX.	Monandria, Diandria, as in classes,			Vanilla, manorchis, helleborine, lady's slipper.
XXI.				Pond-weed, stonewort, bread fruit.
XXII.				Screw-pine, willow, ash.
XXIII.	Monœcia,	Hermaphrodite, staminiferous, and pistilliferous flowers,	on the same plant,	Banana, Indian millet, crosswort.
	Diœcia,		on two plants,	Indian date palm, amber-tree, fig-tree.
XXIV.	Filices,	Ferns,		Polypody, brakes, moonwort, adder's tongue.
	Musci,	Mosses,		Bog moss, earth moss, hair moss, club moss.
	Hepaticæ,	Liverworts,		Horn-liverwort.
	Lichens,	Lichens,		
	Algæ,	Sea-weeds,		Bladder grain.
	Fungi,	Mushrooms,		Truffle, blight.

C. H. Persoon, editor of Linnæus, Paris, 1805–1807, estimates the total number of phonogamous plants thus—Genera, 2303; Species, 20,859; and in Turton's edition of Linnæus, vol. vi., Swansea, 1803, the total of cryptogamous plants gives—Genera, 128; Species, 2923; yielding a grand total of Genera, 2431; Species, 23,782.

The preceding system being now displaced by the natural method founded on the affinities of plants, that is, on the conformity which they bear to one another in their structural disposition, we will present a tabular analysis of the systems of Jussieu, Decandolle, and Endlicher, as developments of the principle, and one or other of which has been accepted under modifications by the best of our modern botanists. The tissue, seed, root, stem, or leaf, and least of all in value, the reproductive organs, supply the means by which this important study is determined. It may be remarked, however, that the natural system is not yet perfected.

NATURAL CLASSIFICATION BY JUSSIEU.—A.D. 1789.

	Description.			Classes.
I. Acotyledonous				1. Acotyledonia.
II. Monocotyledonous	Stamens hypogynous,			2. Mono-hypogynia.
	〃 perigynous,			3. Mono-perigynia.
	〃 epigynous,			4. Mono-epigynia.
III. Dicotyledonous	Apetalous (no petals),	Stamens epigynous,		5. Epi-staminia.
		〃 perigynous,		6. Peri-staminia.
		〃 hypogynous,		7. Hypo-staminia.
	Monopetalous (petals united),	Corolla hypogynous,		8. Hypo-corollia.
		〃 perigynous,		9. Peri-corollia.
		〃 epigynous,	with anthers united,	10. Synantheria.
			with anthers distinct,	11. Coris-antheria.
		Petals epigynous,		12. Epi-petalia.
		〃 hypogynous,		13. Hypo-petalia.
		〃 perigynous,		14. Peri-petalia.
	Diclinous, irregular, flowers unisexual, or without a perianth,			15. Diclinia.

A hundred natural orders, or groups of genera, belong to these classes.

METHOD BY DECANDOLLE.—A.D. 1819.

		Classes.	Sub-Classes.	
I. Vascular or Cotyledonous Plants.	Dicotyledonous or Exogenous.	A. Dichlamydeæ; calyx and corolla distinct	Thalamifloræ; petals distinct, stamens hypogynous.—See Seville bitter orange and Hellebore, in Plate	1. Carpels numerous. Stamens if definite opposite to the petals. 2. Carpels solitary or conjoined, placentæ parietal. 3. Ovary solitary, placenta central. 4. Gynobasic fruit.
			Calycifloræ; petals free, or more or less combined.—See Hemlock and Almond tree, in Plate	1. Polypetalous. 2. Monopetalous.
			Corolifloræ; corolla monopetalous, hypogynous, not attached to the calyx.—See Virginian tobacco, Deadly nightshade, and Poison nut, in Plate.	
		B. Monochlamydeæ; having a single perianth	I. Flowers perfect with stamens and pistil.—See Common mezereon, in Plate. II. Flowers monœcious or diœcious.	
	Monocotyledonous or Endogenous.	A. Phanerogamous; floral envelopes visible and regular	I. Petaloideæ	1. Stamens hypogynous. 2. 〃 perigynous. 3. 〃 epigynous.
			II. Glumaceæ.	
		B. Cryptogamous,	Fructification concealed or irregular.	
II. Cellular or Acotyledonous Plants.		A. Foliaceous,	Having leaves and distinct sexes.	
		B. Leafless,	Having no foliaceous expansions and no evident sexes.	

The figures of plants in the illustrative Plates are appropriated as examples of this system.

METHOD BY ENDLICHER.—A.D. 1836.

Region.	Section.	Cohort.
Thallophyta (θαλλὸς, *frond*, φυτὸν, *a plant*).—Stem and root without opposition. Destitute of spiral vessels and sexual organs. Propagated by spores.	I. *Protophyta* (πρῶτος, *first* or *originating*).—Developed without soil; fructification indefinite. II. *Hysterophyta* (ὕστερος, *posterior* or *derivative*). Developed on decaying organisms; nourished internally from a matrix.	
Cormophyta (κορμὸς, *stalk* or *trunk*).—Stem and root in opposition. Spiral vessels and sexual organs distinct.	III. *Acrobrya* (ἄκρα, *summit*, and βρύω, *to germinate*.—Stem increasing by the apex, the lower part unchanged, and only conveying fluids.	1. Anophyta (ανα, *above*).—No spiral vessels. Both sexes present. Spores free within cases. 2. Protophyta.—Bundles of vessels. No male organs. Spore cases, one or many celled. 3. Hysterophyta.—Both sexes perfect. Seeds without an embryo. Parasitic.
	IV. *Amphibrya* (ἀμφὶ, *around*).—Stem increasing at circumference. Vegetation peripherical.	
	V. *Acramphibrya* (ἄκρα, ἀμφὶ, and βρύω).—Stem increasing by apex and circumference. Vegetation peripherico-terminal.	1. Gymnospermæ (γυμνὸς, *naked*, σπέρμα, *seed*).—Ovules naked. Fecundated at the micropyle. 2. Apetalæ (α, *priv.*, and πεταλον, *petal*).—Perigone wanting or rudimentary, simple, calycine, or coloured; free or adherent to the ovary. 3. Gamopetalæ (γαμος, *union*).—Perigone double, outer calycine, outer corolline; gamopetalous; rarely abortive. 4. Dialypetalæ (διαλύω, *separate*).—Perigone double. Insertion hypogynous, perigynous, or epigynous. Sometimes abortive.

Under the preceding sections this system enumerates 61 classes and 279 orders.

As the determination of the organs is of vast importance to the student of elementary botany, we proceed to give a connected explanation of the remaining Plates under this article, for the purpose of reference.

PLATE I.—SIMPLE LEAVES.

Fig. 1. A circular leaf, one that is perfectly round.
" 2. Leaf approaching to a circular figure.
" 3. Egg-shaped leaf.
" 4. Leaf having an *oval* or *elliptical* form.
" 5. *Oblong* leaf, in which the length greatly exceeds the breadth.
" 6. *Lance-shaped* leaf.
" 7. Leaf of equal breadth throughout.
" 8. *Awl-shaped* leaf, which gradually tapers towards the top.
" 9. *Reniform* leaf, in figure resembling a kidney.
" 10. *Cordate*, or heart-shaped leaf.
" 11. *Lunulate* leaf, resembling a crescent.
" 12. *Triangular* leaf.
" 13. *Sagittate*, resembling the head of an arrow.
" 14. *Cardato-sagittate* leaf, which partakes both of the heart-shaped and arrow-headed figures.
" 15. *Hastate*, or halbert-shaped leaf.
" 16. *Fissured* leaf, parted about half-way down with straight margins.
" 17. *Three-lobed* leaf, divided to the middle into three parts, with convex margins.
" 18. Leaf so blunted at the apex, as to appear bitten off.
" 19. *Lobed* leaf, divided to the middle into several parts, with convex margins.
" 20. *Quadrangular*, a five-angled leaf.
" 21. *Eroded* leaf, the margin sinuated or broken by smaller hollows, as if grooved.
" 22. *Palmate*, or hand-shaped leaf.
" 23. *Pinnatifid*, resembling a winged compound leaf.
" 24. *Laciniate* leaf, irregularly cut or jagged on the edges.
" 25. *Sinuate* leaf, with hollows or wide-gaping breaks on the edges.
" 26. *Dentato-sinuate* leaf, same as before, but with the sinuses indented.
" 27. *Retro-sinuate* leaf, the same, with the sinuses turned backwards.
" 28. *Partite* leaf, deeply divided.
" 29. *Waved*, scalloped or serpentine-edged leaf.
" 30. *Dentate*, or indented leaf.
" 31. *Serrate* leaf, having teeth resembling those of a saw, which point to the apex.
" 32. *Double-serrate* leaf, having a row of lesser serratures placed upon the greater ones.
" 33. *Double-crenate* leaf, in which there is a double row of the segments, termed crenæ, or notches; the lesser placed upon the greater.
" 34. *Cartilaginous* leaf, having a gristly edge.
" 35. *Acute-crenate*, a leaf acutely notched.
" 36. *Obtuse-crenate*, a leaf obtusely notched.
" 37. *Plicate* leaf, plaited like a fan or candle shade.
" 38. *Crenate*, a leaf, the edges of which are cut into small segments, pointing absolutely neither to the acute nor obtuse.

PLATE II.—SIMPLE LEAVES—*Continued.*

Fig. 39. *Crisped*, or curled leaf.
" 40. *Obtuse* leaf, one terminating obtusely.
" 41. *Acute* leaf, terminating in an acute angle.
" 42. *Acuminate* leaf, whose apex is subulate, or awl-shaped.
" 43. *Obtuse-acuminate* leaf, obtuse, with a sharp point, which does not begin till near the apex.
" 44. *Emarginate-acute* leaf, the apex deficient in its margin and ends sharply.
" 45. *Cuneiform-emarginate* leaf, shaped like a wedge, and has a rounded notch at the apex.
" 46. *Retuse* leaf, ending in an obtuse sinus.
" 47. *Pilose* leaf, long distinct hairs proceeding from its surface.
" 48. *Tomentose* leaf, the surface covered with a beautiful down.
" 49. *Hispidose* leaf, the surface covered with hard bristles.
" 50. *Ciliate* leaf, the margin fringed like an eyelash.
" 51. *Rugose*, or wrinkled leaf.
" 52. *Venose* leaf, the surface abounding with branched vessels.
" 53. *Nervose* leaf, the surface abounding with ribs, or simple unbranched prolongations of the pedicle.
" 54. *Papillose* leaf, exhibiting on the surface little bladders or blisters, like nipples.
" 55. *Linguiform* leaf, or tongue-shaped.
Fig. 56. *Acinaciform* leaf, scimitar-shaped.
" 57. *Dolabriform* leaf, in figure resembling a carpenter's axe.
" 58. *Deltoidal* leaf, imagined to resemble the Greek delta, as in black poplar.
" 59. *Three-sided* leaf, as in Lancashire Anthericum, or Asphodel.
" 60. *Canaliculate* leaf, with a channel or pipe-like groove running from the base to the apex and the upper surface, the lower being convex.
" 61. *Sulcate* leaf, furrowed or fluted with a succession of grooves.
" 62. *Cylindrical*, or pillar-shaped leaf.
" 63. *Panduriform* leaf, shaped like a guitar, as Fiddle-Dock.
" 64. *Lyrate* leaf, shaped like a lyre.

COMPOUND LEAVES.

Fig. 1. *Binate* leaf, with two leaflets. This is the lowest modification of the digitate, or fingered leaf.
" 2. *Ternate-sessile* leaf, that is, fingered with three leaflets that are sessile.
" 3. *Ternate-petiolate* leaf, the reverse of preceding, or a leaf having three leaflets that are stalked.
" 4. *Digitate* leaf, fingered in general, but especially applied to five sessile leaflets.
" 5. *Pedate* leaf, resembling a bird's claw, as in Passion flower and Black hellebore.
" 6. *Oddly pinnate*, a winged leaf, with an odd leaflet at the apex.
" 7. *Abruptly pinnate*, a pinnate leaf, which, at the apex, has neither an odd leaflet nor tendril.
" 8. *Alternate pinnate*, the leaflets alternating along the midrib of a pinnate leaf.
" 9. *Opposite pinnate*, a pinnate leaf with opposite leaflets.
" 10. *Interruptedly pinnate*, pinnate leaf with unequal leaflets.
" 11. *Cirrhose pinnate*, pinnate leaf terminated by a tendril.
" 12. *Conjugate pinnate*, the lowest modification of the pinnate or winged leaf, with only two pair of leaflets.
" 13. *Decursive pinnate*, a pinnate leaf in which the leaflets run down or extend themselves into the stalk.
" 14. *Articulate pinnate*, a pinnate leaf in which the common footstalk connecting the leaflets is united.

PLATE III.—COMPOUND LEAVES—*Continued.*

Fig. 16. *Biternate*, or doubly ternate leaf, having the common footstalk divided into three parts, each of which has three leaflets.
" 17. *Triternate*, triply ternate leaf, the common footstalk divided into three parts, each of which is doubly ternate.
" 18. *Bipinnate* leaf, doubly pinnate.
" 19. *Triply-pinnate* leaf, in which each pinna or wing terminates abruptly.
" 20. Triply-pinnate leaf, with an *odd leaflet* at the apex of each pinna.

DISPOSITION OF LEAVES.

Fig. 1. *Inflex*, bent inwards, or towards the stalk.
" 2. *Erect*, leaf nearly perpendicular.
" 3. *Patent*, or spreading leaf, bent outwards, or declining from the stalk at an acute angle.
" 4. *Horizontal*, leaf placed at right angles with the stalk.
" 5. *Reclinate*, bent downwards.
" 6. *Revolute*, the summits rolled inwards.
" 7. *Seminal*, seed leaf.
" 8. *Cauline*, stem leaf.
" 9. *Ramal*, branch leaf.
" 10. *Floral*, leaf stationed near the flower.
" 11. *Decurrent*, a leaf which runs or extends downwards along the stalk beyond its proper basis.
" 12. *Petiolate*, leaf supported on a petiole or footstalk.
" 13. *Peltate*, target-shaped leaf.
" 14. *Sessile*, opposed to petiolate, a leaf seated immediately on the stem or branch, without any manifest footstalk.
" 15. *Amplexicaul*, the leaf transversely embracing the stem by its base.
" 16. *Perfoliate*, differs from the preceding, chiefly in the transverse perforation taking place at a great distance from the margin.
" 17. *Connate*, a leaf formed by the union of two leaves at the base.
" 18. *Vaginant*, or sheathing leaf, by its base longitudinally surrounding the stem.

PLATE IV.—DISPOSITION OF LEAVES—*Continued.*

Fig. 19. *Articulate*, or jointed like the links of a chain. The leaflets in this form are produced each from the summit of

that immediately under it. Ex.: Common Indian Fig, or Prickly Pear.

Fig. 20. *Stellate*, synonymous with verticillate, the leaves surrounding the stem in the form of a radiant star.
" 21. *Quaternate*, a modification of the two last terms, leaves growing by fours.
" 22. *Opposite*, growing in pairs.
" 23. *Alternate*, the reverse of preceding, leaves ranged singly in succession on both sides of the stalk.
" 24. *Imbricate*, leaves are laid like tiles, as in the Saxifrages.
" 25. *Acerose*, or chaffy, leaves pointed like pins, and surrounded at the base by chaffy scales. They are slender, of equal breadth throughout, somewhat hard, also evergreen, as in Fir, Yew, and Juniper.
" 26. *Fasciculate*, proceeding in bundles from the same point, as in the Larch tree and some Pines.
" 27. *Frond*, a term bestowed by Linnæus upon the trunk of the palms and ferns, but now generally disused.
" 28. *Spathulate*, leaf shaped like a spatula, as Rose Cistus, or purple Phlomis.
" 29. *Parabolic* leaf, like the geometrical curve which the term expresses.

Trunks.

Fig. 1. *Squamose*, a scaly culm, straw, or haulm, peculiar to the grasses.
" 2. *Creeping* and climbing stem, as in Bignonia and Ivy.
" 3. *Scaped*, a naked flower-stalk, or trunk, which elevates the fructification, but not the leaves; exemplified in Auricula, and many of the liliaceous plants.
" 4. *Articulate*, a culm or straw that has knots or joints at certain intervals.
" 5. *Voluble*, a twining stem, as in Convolvulus, Black Bryory, and Hop.
" 6. *Dichotomous* (διχα, in two parts, and τεμνω, to cut), a forked stem, that is, one with divisions compounded by pairs, as Forked Mouse-Ear.
" 7. *Brachiate*, a simple stem, whose branches grow by pairs, resembling arms, as Annual or French Mercury.
" 8. *Stipe*, the trunk of a fungus.

Plate V.—Supports and Armature of Plants.

Fig. 1. *Stipule*, one or more scales at the insertion of the footstalks of the leaves and flowers. *Cirrus*, a clasper or tendril.
" 2. *Simple aculei*, prickles proceeding singly from the stem or branch.
" 3. *Triple aculei*, three-pronged prickle.
" 4. *Simple spine*, a single thorn.
" 5. *Triple spine*, triple thorn.
" 6. *Stimuli*, stings as in Nettle.
" 7. *Bracteæ*, floral leaves, differing in colour and shape from the other leaves of plants. They obtain the name of Comæ when assuming the appearance of a tuft of hair at the end of the flower stem, as in species of Sage, Lavender, and Crown Imperial.
" 8. *Concave glands*, usually seated on the footstalk of the leaves.
" 9. *Pedicellate glands*, placed on short footstalks, having their seat on the petiole.
" 10. *Pili*, hairs, a species of pubescence.
" 11. *Thorny* leaf and branch.
" 12. Prickly capsule of the Beech.
" 13. *Pedunculus*, a flowerstalk.
" 14. Thorny fruit of the Horse Chestnut.
" 15. Prickly fruit of the Chestnut.

Plate VII.—Roots.

Fig. 16. *Dentate*, roots with granulations or knobs resembling teeth, as in Primrose.
" 17. *Palmate*, hand-shaped root as in Orchis.
" 18. *Creeping* roots with horizontal extensions, or radicles, at certain intervals, as Couch-grass.
" 19. *Bulbs* produced in the angle formed by the leaf and branch, as in Pilewort.
" 20. Roots sent forth from the *midrib* of a leaf, as in Cuckoo-flower.
" 21. Roots produced from the *joints* of the stalk, as in Common Creeping Cinquefoil.

Parts of Fructification.

Fig. 1. *Perianth*, flower cup, properly so called.
" 2. *Amentum*, catkin.
Fig. 3. *Spathe*, a sheath, as in Narcissus.
" 4, 5. A perianth, which has a row of leaves distinct from the flower, and surrounding the base, as in Pink.
" 6. *Universal involucre*, the calyx or cover of an umbelliferous flower placed under the large or general umbel.
" 7. *Partial involucre*, the cover of an umbelliferous flower, placed under the smaller umbel.
" 8. *Calyptra*, calyx of the mosses.
" 9. *Volva*, calyx of the fungi, or mushroom tribe.
" 10. *Gluma*, the husky calyx of the grasses.

Plate IX.—Parts of Fructification.

Fig. 14. *Campanulate corolla*, bell-shaped flower.
" 15, 16. Modifications of the same.
" 17. *Infundibuliform* corolla, funnel-shaped flower.
" 18. *Hypocrateriform* corolla, salver-shaped flower.
a, the limb, or upper spreading part of the petal.
b, the tube, or lower hollow part.
" 19. *Cruciform* corolla, cross-shaped flower.
" 20. The petal of preceding; the upper spreading part of the petals is termed lamina, the plate or border, the lower tapering part is the unguis or claw.
" 21. *Rotate* corolla, the back or under side of a wheel-shaped flower.
" 22. The front or upper surface of the same flower.

Nectarium.

Fig. 1. The flower of Aconite, or Monkshood.
" 2. Horned nectaries of the same, being two fistular nodding bodies resembling stamina, with an oblique mouth and recurved tail, seated on long awl-shaped footstalks, and completely hid by the upper helmet-shaped petal.
" 3. Bell-shaped nectary, as in Rush-leaved Narcissus.
" 4. *Glandular* nectary of Willow.
" 5. Nigella, Fennel flower, or Devil-in-a-bush.
" 6. The eight-lipped nectaries of the same.
" 7. Trapæolum, or Indian cress, the nectary of which, resembling a cock's spur, terminates the calyx.

Plate X.—Parts of Fructification—*Continued.*

Fig. 1. *Germen*, or seed-bud of poppy, crowned with its flat, radiated, and target-shaped stigma.
" 2. The different parts of a *pistil*, or female organ of generation, viz., stigma, style, and germen.
" 3. Another illustration of the same.
" 4. Pistil of Iris.
" 5. Pistil, with a three-cornered stigma, germen, and no style.
" 6. Pistil of Tree-primrose; *a*, quadrifid stigma; *b*, style; *c*, germen.
" 7. Tree-primrose; *a*, pistil; *b*, stamens; *c*, petals; *d*, upper spreading part of the calyx; *e*, tube, or long cylindrical lower part; *f*, germen.
" 8. Parts of a *stamen*, or male organ of fecundation; *a*, the anther; *b*, the filament; *c*, the pollen, or fertilizing dust.
" 8½, 9. The singular nectaries of Parnassia.
" 10. Passion flower, with its nectary, termed by Linnæus a triple crown.
" 11. Nectary of Crown Imperial, forming a pit in the base of each petal.
" 12. Five-horned nectaries of Columbine.
" 13. A nectary of Columbine detached from the flower.
" 14. Fringed or bearded nectary of Iris.

Modes of Flowering.

Fig. 1. *Verticillus*, a whorl.
" 2. *Fasciculus*, bundle or bunch.
" 3. *Spika*, the mode of close inflorescence in the ears of wheat, rye, or barley.
" 4. *Racemus*, cluster as of currants or grapes.
" 5. *Panicula*, a mode of loose inflorescence resembling that of oats and other grasses.

Plate XI.

Fig. 6. *Thyrsus*, panicle contracted into an oval form.
" 7, 8. *Cyme*, a species of inflorescence differing from an umbel, in having the partial footstalks placed without any regular order.
" 9. *Corymb*, a mode of flowering, distinguished from an umbel by the unequal length of the footstalks, which do not, as in the umbel, proceed from the same centre, but are produced from different parts on both sides of the stalk.
" 10. *Capitulum*, a little head.

PERICARP, OR SEED VESSEL.

Fig. 1. *Capsule* with an undivided cavity or single cell.
" 2. *Capsule* with two cells.
" 3. *Capsule* with three cells.
" 4. *Capsule* with four cells.
" 5. *Capsule* with six cells.
" 6. *Capsule* with many cells.
" 7. That species of pod termed *legumen*, in which the seeds are fastened along one suture only.
" 8. *Follicle*, a species of dry seed vessel, that opens longitudinally on one side from bottom to top, and has the seeds loose within it.
" 9. Represents that pulpy kind of pericarpium, termed pomum, with its enclosed capsule, having five cells, in which are contained the seeds.
" 10. *Drupe*, a pulpy seed vessel of the cherry kind, containing a nut or stone.
" 11. Section of a drupe, exhibiting the pulpy part and the stone.
" 12. A nut or seed covered with a shell.
" 13. *Strobilus*, a cone.
" 14. *Bacca*, or Berry, a pulpy pericarp without valves, enclosing naked seeds.
" 15. Transverse section of a Bacca, exhibiting the disposition of the seeds within the pulp.
" 16, 17. That species of pod termed *siliqua*, in which the seedsare fastened to both sutures, or joinings of the valves, alternately.

CHEMICAL MANUFACTURES.

CHAPTER VI.

ALUM.—Here we have another valuable article, curiously dependent for its production on the agency of sulphuric acid, either naturally or artificially; and its production involves many features well worthy of attention.

It will be well at once to anticipate the question, what is alum?—and to give an answer to it. We know that, externally, alum presents the appearance of a whitish crystalline substance; but there is nothing to indicate to the eye that this substance is formed of the three singularly opposite ingredients—sulphuric acid, clay, and potash. Yet such is the case; and we here have one of the many startling facts which chemistry presents. In chemical language, alum is a "sulphate of alumina and potash" (soda or ammonia being sometimes substituted for potash); the alumina is the basis or foundation for all varieties of clay, and derives its name from being an invariable ingredient in alum. Dense and opaque as clay is known to be, even in its pure state of alumina, yet it contributes to the formation of the transparent alum so familiar to us.

These, then, being the three ingredients, the next question naturally would be—are they met with in a combined state, or do they require to be mixed artificially? Both are true; nay, there are even four modes of union: for in some cases crystals of alum are found ready formed in the earth—in others, the three ingredients are met with in the same ore, but not combined into alum—in others, part only of the crude ingredients is found in the ore, and requires the addition of the rest—and in others, the whole are combined by artificial means. The subject of alum-making becomes thus a somewhat complex one; but we may perhaps manage to obtain a few general ideas on the matter, without involving the niceties of chemical detail. As respects native alum, it has been found in the form of crystalline needles in some part of the Andes of South America; in the form of a kind of earthy alum, met with in another part of the same chain of mountains; in the form of long thin fibres, having soda instead of potash, and occurring in a third district of the Andes; and in the form of a mineral called *aluminite*, found in some parts of Germany. In all these cases the ingredients are found combined into a state nearly analogous to alum. To go to the opposite extreme, we find that in France—and also at Newcastle—the alum is wholly an artificial product, formed by mixing clay, sulphuric acid, and potash, so as to lead to chemical combination.

The intermediate modes of formation, that is, those which are in part natural and in part artificial, are of more extensive occurrence; in Italy, in Hungary, in Sweden, in Scotland, and in Yorkshire, we find examples. Various ores or earths, called *alum-stone*, *alum-slate*, *slate clay*, and *bituminous shale*, furnish the main material; and these, treated in various ways, yield the greater part of the alum of commerce. For instance, at Tolfa in Italy, alum is made from alum-stone. Nearly four centuries ago, a Genoese merchant, who had seen alum-ore in Turkey, observed that at Tolfa trees were growing such as he had seen near the alum-pits in Turkey; and he thence conjectured that alum-ore might exist there. His conjecture was correct, and alum-works were soon established, which have existed ever since. The Tolfa alum-stone contains all the three ingredients, which, after the stone has been roasted, crumbled into powder, and boiled, combine and crystallize in the form of alum, without the addition of any new ingredient. In Sweden the ore employed (containing a little potash) is alum-slate, which, besides roasting, requires the addition of other ingredients before alum can be formed.

In Yorkshire there are three alum-works. In Scotland there are four, two a little northward of Glasgow and two a little southward. The Yorkshire works, which are near Whitby, originated thus:—Sir Thomas Chaloner, who had an estate near Whitby in the time of Charles I., found alum-ore near the coast, and was desirous of working it; but as there was no one in England at that time who understood the art of making alum, he privately engaged men from Tolfa. The Tolfa works, being very profitable, had from the first belonged to the popes, who, like monopolists generally, tried hard to preserve the whole affair to themselves; the workmen who joined Chaloner were threatened with anathemas and excommunications, but all in vain, for the Whitby works soon became flourishing. Chaloner afterwards had a disagreement with Charles I. respecting the works; for the king, after granting him an exclusive patent, sold half the patent to another party, as a means of procuring money; and this is said to have led ultimately to the active part which Chaloner took against the king in parliament. The Whitby district, where these works are established, is a remarkable one. It consists of precipitous cliffs containing alum-slate, bordering on the sea, and stretching to a distance of about thirty miles along the coast of the German Ocean. The alum-slate is covered with ironstone, sandstone, alluvial soil, and a few other matters; and when these are removed, the rock is broken piecemeal by picks and javelins, roasted, evaporated, and otherwise treated so as to yield alum.

There is a firm at Glasgow to whom three out of the four Scotch alum works belong; viz. two near Campsie, and one near Hurlet. Either one of these will suffice to show the general character of all; but we select the latter as being, from its great extent, well worthy of attention. The Campsie works are situated among the Campsie Hills, a few miles north of Glasgow; while the Hurlet works are a few miles south of Glasgow; both are situated in a partially-exhausted coal district, for reasons which will presently appear.

A pleasant ride of half a dozen miles from Glasgow, or a railway trip to Paisley, as part of the distance, brings us to an open part of the country, whose green fields give but little indication of the burrowing which has gone on beneath them. On arriving near the village of Hurlet, however, here and there streams of smoke are visible, which point out the localities of certain alum, iron, and lime-works; and these indicate that the mineral riches beneath are not confined to one kind alone. The country around is undulated with gentle hills and hollows; but still there is a grassy covering which effectually conceals these underlying beds. It is not till we enter the precincts of any of these works that we find the pits which open up a communication between the world above and the world below; and even there we see little from

whence a judgment might be formed of the honeycombed condition of the ground beneath: we must grope, *in propriâ personâ*, through miles of shallow, dark, arched passages, regardless alike of water, mud, coal, and alum, before we can rightly understand the "whereabouts" of the mines.

When within the boundary of the alum-works, we find an extensive area of ground, occupied in part by buildings where the preparation is conducted, in part by open pits where the ore is steeped, and in part by huge heaps of earthy matter either still burning or lying useless after being burned. It is one consequence of the condition in which the ingredients for alum are found in the ore, that a large mass of earthy refuse is separated as an incumbrance; and this refuse is accumulated in enormous ridges and hillocks, until taken away to be used for footpaths or in the formation of railroads. There is no large factory, no many-storied building with its various rooms filled with workmen; the buildings being only such as are necessary to enclose the furnaces, the boilers, the tanks, the coolers, and the other vessels required in the process; together with the water-wheels which raise the ore from the pit, and pump liquid from one vessel to another.

In such districts as this, the possession of a mine by no means implies the possession of the ground above it; the two are held by different tenures, and are leased, or may be leased, independently of each other. Nay, not only so; but if the mineral strata beneath comprise more than one kind, each kind may be leased separately, and to a different person from those who lease the rest. Something of this kind occurs at Hurlet. The property is owned by the Earl of Glasgow and other parties, and the surface-ground is leased off in the usual way; but as there are four kinds of mineral produce beneath—coal, iron, lime, and alum—the lessee of the surface-ground has, as such, no interest in these sources of wealth: other leases are granted, according to the kind of mineral which is to be worked; and thus there may be four or five leases, and as many lessees, co-acting at the same time in one place. For instance, the Hurlet Alum Company rent all the alum found throughout a certain extent of country, but have nothing to do with the iron, the coal, or the lime found in the same pits which yield the alum, those ores being leased to other parties. It thus arises that there may be, and are, different sets of miners at work at one time in the same series of labyrinthine passages, some to collect one kind of material and some another; each party independent of the others, in respect to the contract with the employers, the mode and rate of payment, the kind of tools employed, and the general mode of procedure. This explanation will enable us better to understand what meets the observation when down in the pits.

The alum-ore is drawn up to the surface near the buildings where the subsequent processes are conducted; but the men descend to the mine at the distance of half a mile from that spot, the same shaft serving for the various classes of miners. This shaft is in the middle of a field, and presents to view nothing more than a square opening measuring about six feet each way, guarded by slight wooden palings at the margin, and having ladders of very small steps for the descent. The depth is not very great—insignificant, indeed, when compared with that of the mines whence metallic ores are procured; and hence the descent has nothing about it very fatiguing. But once arrived at the bottom, we are just as much excluded from the light of day, and are exposed to the same rough usage, as if we were ten times as far beneath the surface. An old coat and cap, a thick pair of boots, a little lamp, and a little courage, must prepare us for our groping excursion; and we soon find that not one of these can well be spared.

When we follow our guide from the bottom of the descent into the passages of the mine, the profound darkness has at first a very bewildering effect; for the earthy lining of the passages is so nearly black, that it reflects very little of the light from the small lamps carried in the hand, and thus the lamps seem like so many specks of light set in—nothing. Under-foot the soil is rather wet and sloppy, and over-head the roof is so low, that a stooping posture is unavoidable. By degrees the eye becomes accustomed to the peculiar gloom of the place; the lamps, which at first only rendered the "darkness visible," now throw a faint glimmer upon a few prominent points, from which we find that we are walking through a low-arched passage.

On the occasion when the writer groped through this mine, he accompanied two of the managers, one of whom had cognizance of and superintendence over the operations for the collection of alum, while the other superintended the coal and lime miners; and an opportunity was thus afforded of seeing most of the operations going on. After having walked "in single file" for some considerable distance, we came to the spot where a number of glimmering lights showed that mining operations were being carried on. Some men were seated about on heaps of coal, nearly shrouded in darkness; while others, with bits of lighted candle stuck in their caps, were digging and shovelling coal. One man was preparing a blast; that is, he was placing gunpowder in a cleft of solid coal-rock as a means of riving it. When his operations were completed, all the men retired to a respectful distance, there to remain till the explosion was over; and this interval of a few minutes, though mere matter of course to the miners themselves, is suggestive of some awkward thoughts to those who are new to the subject; for an indefinite expectation of some mischief, which we can neither measure nor guard against, is very apt to arise. However, in the course of a few minutes the fuse was kindled, and the gunpowder exploded; and it was then to be seen that a large mass of coal had been loosened from its bed, upon which the miners immediately set to work.

Having left this spot, we continued our groping through a long series of arched passages; some wet underneath, some dry; some having a railway on the floor for drawing up the "corves" or baskets of coal from a lower level: some high enough to permit walking in an erect posture, others (and these the greater part) so low as to render a painful stooping posture indispensable; some several feet wide, others wide enough only for one person to pass at a time. These passages branched out from one another at all angles, and in all directions, till no one but a practised person could form the least conception of the course we were taking, whether away from or round again towards the entrance. For the most part these passages were deserted coal-strata; all the coal having, in the course of years, been removed, except certain portions which were left as pillars to support the roof; and as the stratum of coal thus removed declined at a certain angle in one direction, the void passage acquired the same slope, and thus the transit through the mine is an incline, upward or downward according to the direction.

At one part of the mine we came to a spot where a party of lime-miners were at work. The lime was in the form of very hard stone, and the removal of it was severe labour. The number of lights being considerable, and the white stone affording a good reflecting surface, this part of the mine was more visible than any other. The men had the upper part of the body naked, with the exception of the cap which held the bit of lighted candle; and some, in the intervals of work, were seated on low heaps of stone or rubbish, smoking their short pipes. As to their conversation, it was very little more to be understood by a stranger than Gaelic would have been; for the miners' language is full of words not in use elsewhere, or else differently applied. For instance, in the lead-mines of Derbyshire, a "coffin" is an old working open to the day; a "country" is a rock through which a vein traverses; and "trade" is rubbish or refuse from a mine: again, in Cornwall a "trouble" is a break in the continuity of a vein; an "old man" is a place worked in former ages; and so forth—many of the terms and phrases being common to all miners, while others are peculiar to certain localities. Another group of miners, warming some oatmeal "parritch" over a small fire, and enveloped in the smoke, formed a curious patch in the dusky landscape.

While walking along the arched passages, if the hand were passed over the surface of the roof, or if the head—from want of proper humility—struck against it, we could easily

see that the roof was coated with a crumbling powdery substance, easily scraped from the solid rock. This was a decomposed state of the mineral which was afterwards to yield not only alum, but also copperas; the air and damp of the mines having in the course of years brought to an efflorescent state that which would otherwise have been a hard stony substance. In other parts of the vaulted passages, specimens might occasionally be picked up, in which a hard slaty substance was interstratified with layers of a greenish-white crystalline body; while in others, again, a brownish-black kind of coaly-slate was the form in which the alum ore presented itself, always occurring *above* where the coal had been, and never below it. At another place, being the lowest part of the mine, an area of several acres of water had collected, entirely occupying the deserted workings at that part. This water, when tasted, was found to be strongly impregnated with the two salts—copperas and alum—resulting from the decomposition of the alum-ore which had dropped into the water, or over which the water had trickled.

After groping in this way for three hours, to a distance of four or five miles through the apparently interminable passages of the mine—some of which belonged to one proprietor, some to another, but all leased (in respect to the alum) to one party—we returned to the entrance; not unwilling to exchange a stooping attitude and a dim glimmer for free movement and the light of day.

Let us next see the processes to which the alum-ore is subjected. In these mines there was originally a stratum of coal, with a stratum of lime above it, and between the two a thin stratum (varying from two to twelve inches in thickness) of ore containing most of the chemical elements for alum. So long as the coal was not worked, the alum probably remained undisturbed, or at least unworked; but when the whole stratum of coal was removed, the slaty stratum above it was laid bare. In this slaty stratum there are, among other elements, sulphur, alumina, and iron; and these, by the long-continued action of air and moisture, lead to the formation of sulphate of alumina and sulphate of iron. But heat will also lead to this transformation; and thus the operations of the alum-works involve two varieties; one for the efflorescent ore, and the other for the stony ore.

Supposing the crumbled ore (which has a greyish colour and a salt taste) to be scraped and collected from the pit, it is put into large open depositories called *steeps*, freely exposed to the air. It is there covered with water partially impregnated with sulphate of iron and alumina, and allowed to remain undisturbed for several hours, during which time the sulphates become dissolved in the water, and the earthy residue subsides. The water, having imbibed the saline matter from the ore, is drawn off to a settling cistern, and the half-spent ore is steeped again and again with fresh water, until all the soluble matter is completely exhausted.

In the cistern the earthy sediment wholly separates, and from thence the liquor is pumped into a series of long-arched boilers, so formed as to apply heat to the surface of the liquid. By this means a considerable portion of the water is evaporated, and the highly concentrated liquor is then transferred to large coolers, where it remains about a fortnight undisturbed. During this interval a process of crystallization goes on: the liquor contains sulphate of iron (copperas) and sulphate of alumina, and the former of these separates from the latter by gradually crystallizing. Sticks called "riders" are immersed in the liquid in the coolers, and around these sticks large bundles of beautiful green crystals collect, forming the well-known but absurdly named "copperas" of the shops.

When the crystals of copperas have been removed, the remaining liquor is drawn off into an evaporating boiler, in order that the sulphate of alumina may go through the same process as the copperas; and, after boiling to a certain strength, the liquor is drawn off into a cooler. Sulphate of alumina will not crystallize without the addition of potash or some other alkali, and potash is therefore put into the cooler with the liquid, by which, after some days' standing, crystals of alum are produced, those crystals being a sulphate of alumina and potash. After this follow other processes of boiling, evaporating, and crystallizing, for the purpose of purifying the alum—processes which give rise to the distinctions of "green alum," "white alum," and "finished alum;" but into these details we need not enter.

When, instead of the efflorescent or powdery ore, the hard or stony ore is used, a preparatory process is necessary. This ore (which in appearance is somewhat midway between slate and stone-coal) contains sulphur, iron, and alumina, like the decomposed ore; but these three elements have not yet been combined into the sulphates of iron and of alumina; and the aid of fire is necessary for this transformation. The ore, after being broken into small pieces, is built up into long ridges, with fuel beneath and air-holes in different parts; and here it is burned as a preparative process.

It will thus be seen that the copperas is an extra prize which the alum-maker obtains from the ore, when the latter has been decomposed by the air; and that the four main processes, varied somewhat in detail, are roasting, steeping, boiling, and crystallizing; and the alum thus made is forthwith ready for use in dyeing, in tanning, and numerous other branches of manufacture.

This, then, is the process for obtaining alum from the crude ore; but we must now notice the mode of preparing it from the elements themselves, as practised at some of the large chemical works. As we before observed, crystallized alum is called chemically a "sulphate of alumina and potash," being composed of sulphuric acid, alumina or pure clay, and potash; and provided those three agents can be properly brought together in proper proportions, they will still form alum, whether derived from decomposed ore, or from the mixture of the different agents.

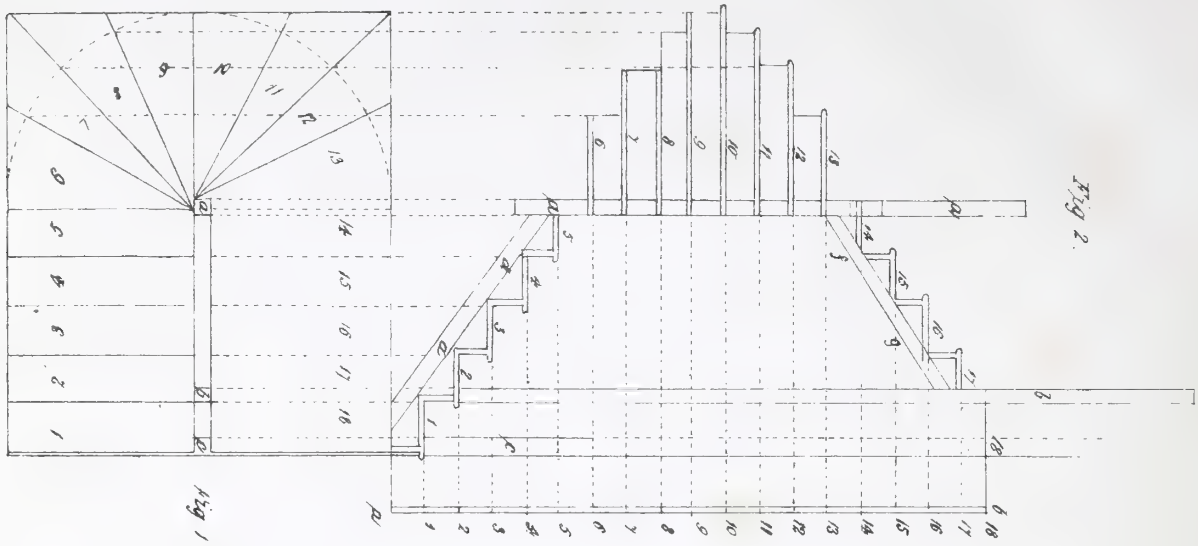
The buildings appropriated to the alum manufacture have their own vessels and their own peculiar arrangements, some of them very interesting. The alumina is procured from Cornish clay, a fine, smooth, and white clay, which is extensively employed in the manufacture of porcelain and the finer kinds of pottery. This clay is brought from Cornwall in balls or blocks, as dug out of the earth, and is ground under a heavy stone to a state of great fineness. The powdered clay is calcined in an appropriate oven, to drive off the moisture and vegetable matter which may be combined with it. The calcined clay is next placed in an oval tank sunk in the ground; and to this is added the second ingredient necessary to form alum—that is, sulphuric acid. The acid has such a powerful action on the clay, that the two together soon form a boiling mixture, although no heat whatever is applied to it; the instance being one of those in which rapid chemical combination gives rise to the evolution of heat.

When these two agents have combined, they are mixed with a considerable quantity of water, and allowed to settle, by which those solid parts of the clay which resist the action of the acid are allowed to fall to the bottom of the vessel. The liquid (which is a solution of sulphate of alumina) is then pumped up into leaden vessels, where it receives the addition of some sulphate of potash, as a means of giving the third ingredient necessary to the formation of crystallized alum. The different ingredients are allowed to remain quiet in a circular sunk vessel, where the alum gradually crystallizes round the sides, shooting forth large crystals towards the centre, where the mother-liquor (or portion which will not crystallize) remains.

But the alum thus produced is not pure and fine in quality. It undergoes the process of *roaching*, to bring it to a better condition. This roaching (or roching, as it may perhaps more properly be spelled) is probably meant to imply the production of an alum similar to roch alum; and this latter derived its name from Roccha in Syria, where it was first made. In the process of roching, steam is allowed to act upon the alum, so as to dissolve it, and to make with it a very strong solution. This is done in a leaden vessel; and from this vessel the solution is transferred to large cylindrical crystallizing vessels, where it attains the final state in which it is sent to market.

When the crystallization is complete, the cylindrical vessels

PLATE G.



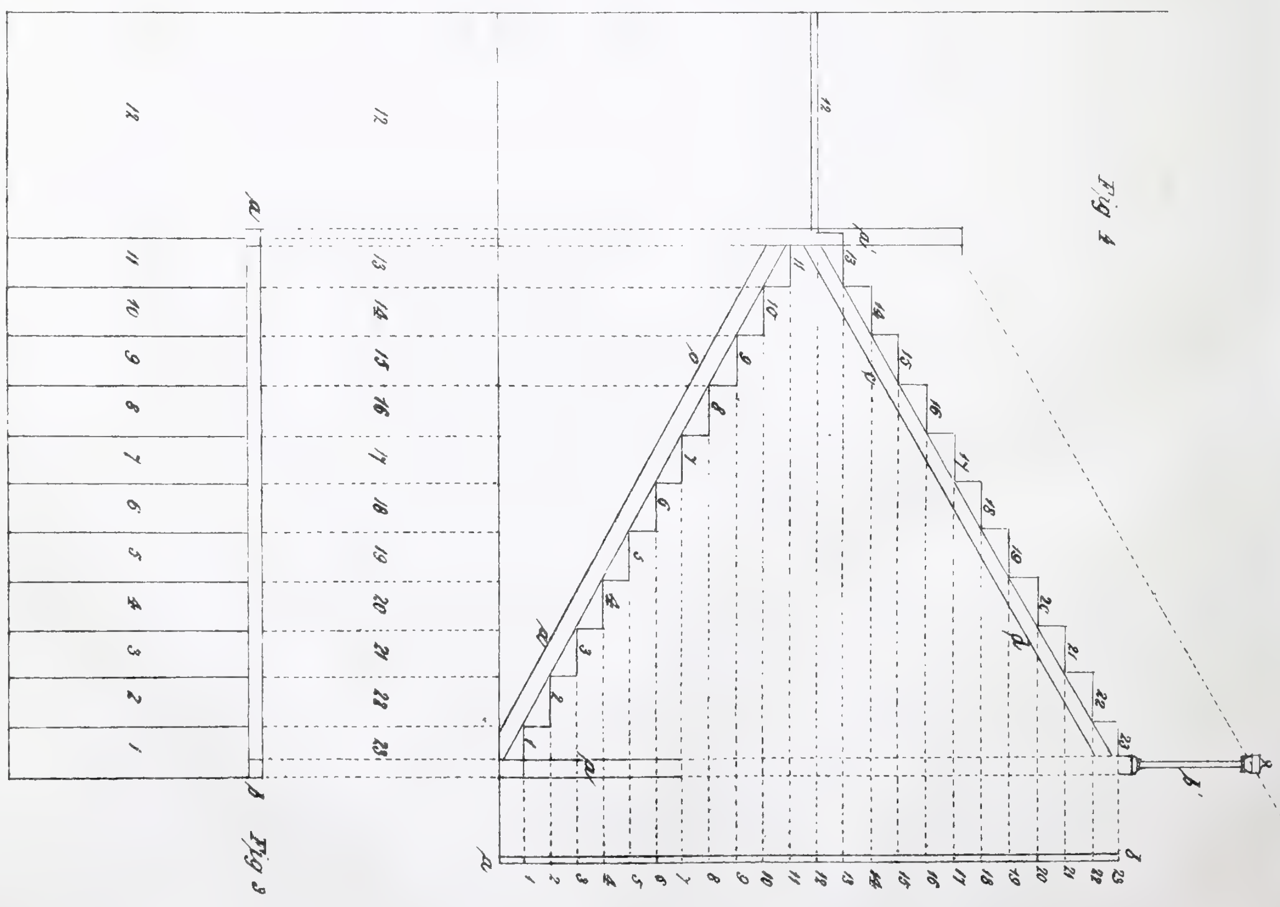


PLATE O.

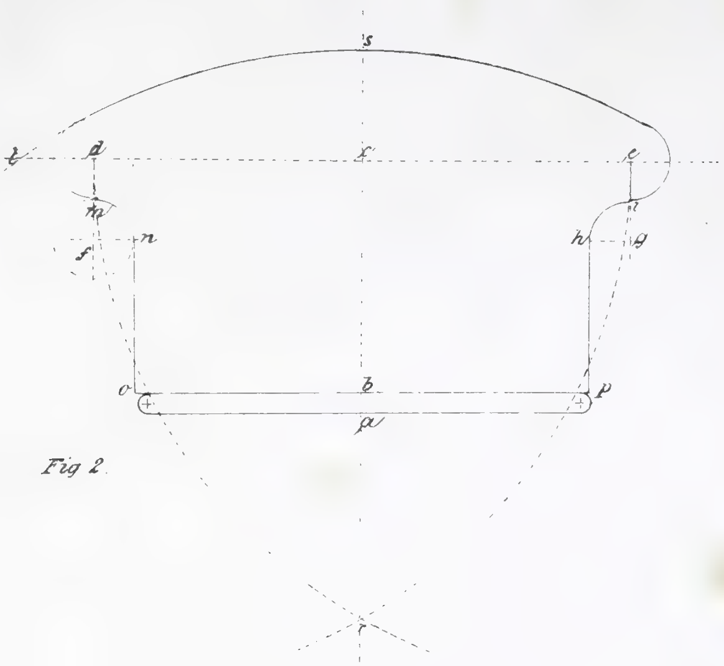


Fig 2.

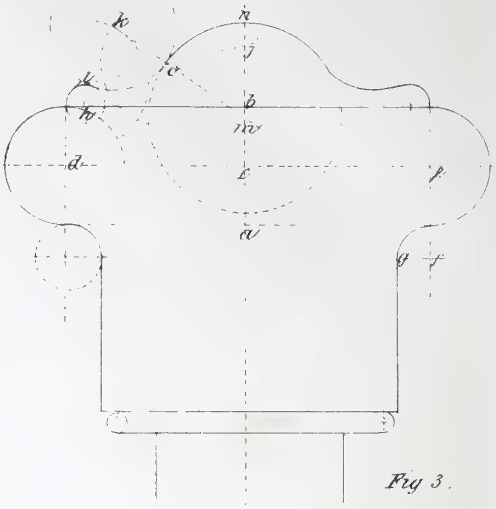


Fig 3.

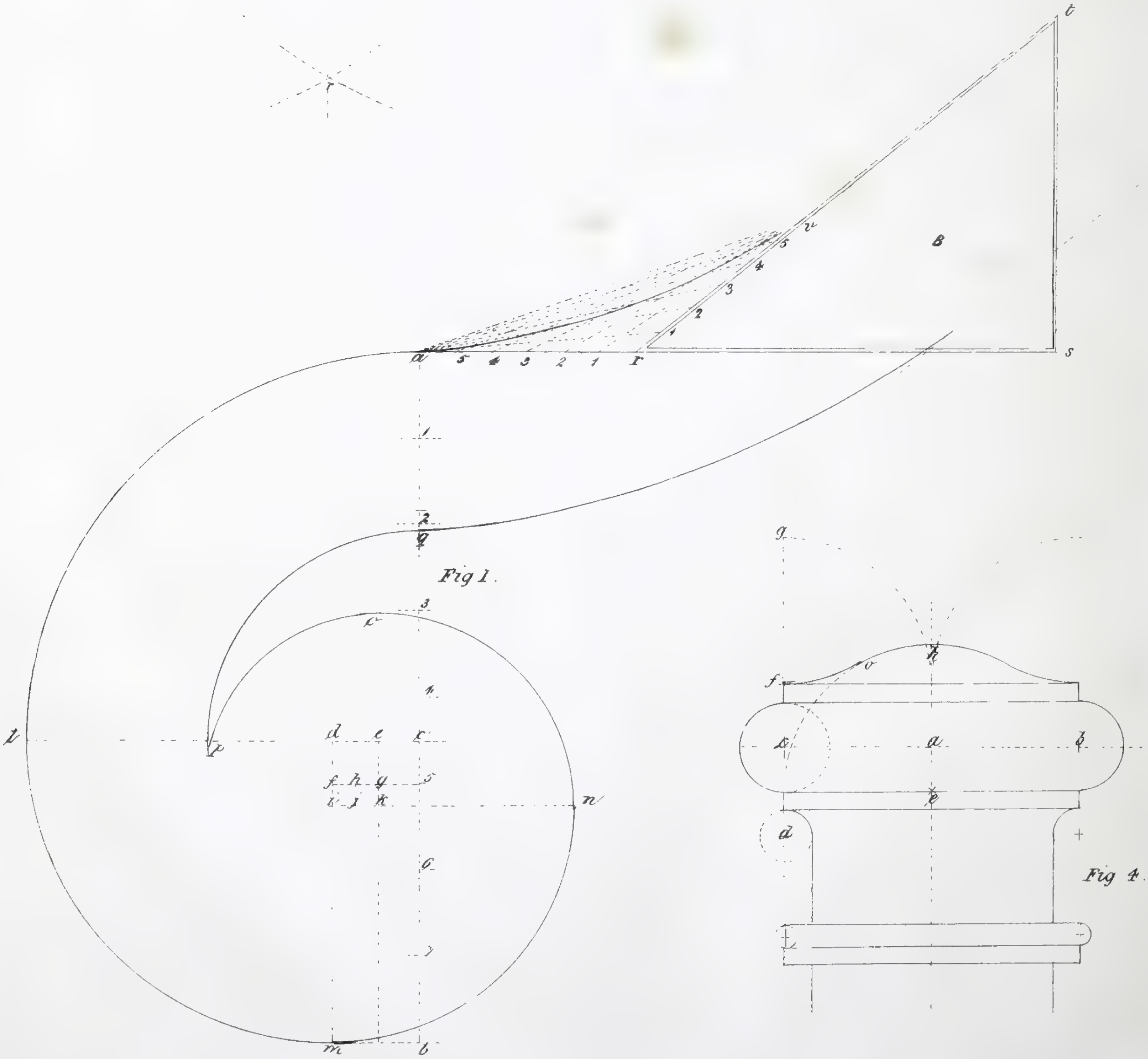


Fig 1.

Fig 4.

present a very beautiful exemplification of this kind of chemical action. They are about seven feet high by five in diameter; and upon looking in at the top of any one of them, we see a thick hollow cylinder of crystallized alum, with a portion of floating water in the centre: the mass appears like an irregular rock-work of sparkling transparent crystals, many of them of large dimensions, and all with the most perfect symmetry of form, presenting the keen apex, the fine, clear, straight edges, and the regular and even faces of the "octohedron," the geometrical form which these crystals assume.

The manner, too, in which the alum is extracted from the vessels is calculated to show the beauty of the crystallization. The vessels are capable of being taken to pieces as they stand, by the removal of certain hoops and staves; and the alum is then exhibited to the eye, as if it were one magnificent cylindrical crystal, as large as the interior of the vessel had been. The liquor is removed from the inside, and the alum, being broken up into convenient fragments, is packed in barrels for the market.

There is one peculiarity about alum which has led to an entirely new branch of manufacture, now being carried on extensively at one of the large works. We have said that it is a sulphate of alumina and potash. But it is not necessarily so: in some instances soda, in others ammonia, has been used instead of potash. The truth is, that these ingredients are used chiefly as agents to induce the crystallization of the alum. Sulphate of alumina will not crystallize; the sulphuric acid and the alumina have combined, and the resulting compound possesses most of the useful properties of alum; but it cannot, by itself, be brought into a crystalline form. When, however, any one of the three above-mentioned alkalies is added, the sulphate acquires this power, and becomes a crystallized sulphate of alumina and alkali. On the other hand, this alkali is of no practical service in the chief purposes to which alum is applied in the arts: the sulphate of alumina is the real working agent; and if this could be obtained in a pure state and in a solid form, the alkali would in most cases be unnecessary. It happens that the iron contained in small quantity in the clay, and which would injure the alum if allowed to form one of its constituents, is with difficulty removed except by some mode of crystallizing the alum; and it is not until recently that the difficulty has been practically removed by the production of a "patent alum," the chief characteristic of which is, that it possesses the efficient properties of alum, but without containing potash. In making this alum, sulphuric acid and Cornish clay are used, as in the other case; but the clay is used in greater proportion, so as to form a kind of mortar or thick paste. This mortar is placed in a heated trough, where the moisture is so far evaporated as to convert the mass to the form of a dry earth. From the trough it is removed to tanks, where water is employed to dissolve it; and while in the liquid state the composition is acted upon by an agent intended to remove the iron: this being the only contained ingredient which is injurious to the alum. The agent employed attracts or combines with the iron existing in the clay, forming with it the coloured pigment known as prussian blue. This prussian blue is allowed to subside, and the remaining liquor, being a solution of sulphate of alumina, is boiled till all the water is driven off. The solid residue is formed into cakes an inch or two in thickness, and in this form it comes into the market. Instead of being a crystal, it is an opaque earthy solid, differing from common alum in the circumstance of containing no potash, but possessing in common with it the qualities which render it valuable in the arts.

The prussian blue is procured in far too large quantity to be allowed to remain in that state: it is restored again by chemical means to the form which it before presented, ready to be again used in making more alum. This principle is exhibited in many departments of a chemical work: where a chemical substance, after being modified in its character by the aid it has afforded in making other substances, is restored to its original form, and thereby fitted to render similar aid in other instances.

In many of the works where these complicated processes are being carried on, the mechanical arrangements are on a very large scale. In one that we have seen, there are five steam-engines in different parts of the works, for pumping up water, pumping liquids from one vessel to another, setting in motion the mills and stones for grinding clay and lime, and other operations requiring great motive power. There are carpenters' shops, smiths' shops, coopers' shops, plumbers' shops, and others of a similar kind for keeping in working order the various vessels employed in the works; the lead vessels and pipes, especially, are so numerous, that there is constant work for plumbers in one way or other. There is also an important department which we may, perhaps, term the very grammar of the whole, viz. the *laboratory*, the spot wherein are determined the numerous points connected with the chemical science of the manufactures. This laboratory contains all the appliances for such a purpose—air-furnaces, reverberatory furnaces, sand-baths, stills, retorts, and the varied apparatus for experimental trials on the mutual action of chemical agents. A chemical library, too, is a necessary appendage to such a place.

When, leaving the actual buildings themselves, we go out upon the spoil-bank or mound of rubbish, we there get a bird's-eye view of the arrangements whereby the works are connected with the means of transit. Railways traverse the ground in all directions, affording easy means of communication. In the first place, the coarse materials, such as sulphur, salt, lime, coal, &c., are landed at a wharf, and are thence hauled up an inclined railway, through a tunnel, to the works, by means of steam-power; and when arrived there, other railways convey these materials to the various buildings wherein they are to be brought to bear upon the manufactures. Then, when the manufactured goods are finished, the same system of railways furnishes a medium for conveying them down to a busy river, there to be shipped off to various quarters.

Such are chemical works. Some manufacturers make one kind of acid or alkali, some another; one firm may have a reputation for a particular kind of salt or chemical agent, another for another; and, to understand the minute details, it would be necessary to follow the manufacturing routine of all the substances one by one. But the broad principles are the same in all. There is in all of these works the same exhibition of lofty chimneys, large and variously arranged buildings, furnaces, and ovens in almost endless variety, boilers, heaters, coolers, stills, crystallizing vessels, cisterns, tanks, pans, and a multiplicity of other apparatus; while they all likewise agree more or less in this—that there is no lack of odours from some of the chemicals under process of manufacture. It is perhaps scarcely necessary to remark, that the shops of the chemists and druggists are supplied with drugs of these various kinds from the chemical works, through the agency of wholesale dealers. There are in London several wholesale druggists who accumulate in their warehouses the crude drugs from every part of the world, not only from the chemical manufacturers, but from foreign merchants and dealers; and these drugs, passing into the hands of the retailers, are by them sold in smaller quantities, or are made up into the various well-known pharmaceutical preparations.

ILLUSTRATIONS OF MECHANICAL DRAWING

SECTION SECOND.

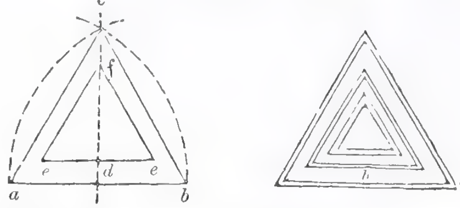
THE DELINEATION OF ARCHITECTURAL SUBJECTS.

We propose, in the preliminary lessons of this department, to show the use of geometrical construction in the delineation of subjects met with in architectural drawings.

The lesson in fig. 115 shows the method of delineating the triangular panel at *b*, this being in form what is known as an "equilateral triangle." Draw the line, *a b*, to correspond with

the base of panel; from *a* and *b* as centres, with *a b* as radius, describe arcs cutting in *c*; join *a c*, *b c*. Parallel to the sides

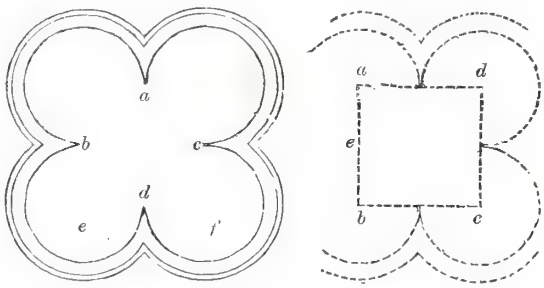
Fig. 115.



of this draw the lines, *e d e*, *e f*, *e f*, the distance between the two triangles being obtained from the diagram to the left.

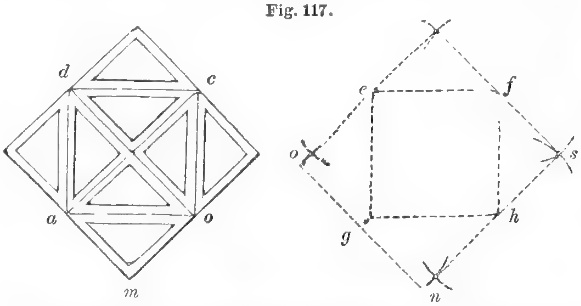
To draw the "quatrefoil" in fig. 116. Draw lines, *a d*, *b c*, parallel to and distant from each other equal to *a d*, and also *a b d c* equal to *b c*, and intersecting each other in the points, *a b c d*.

Fig. 116.



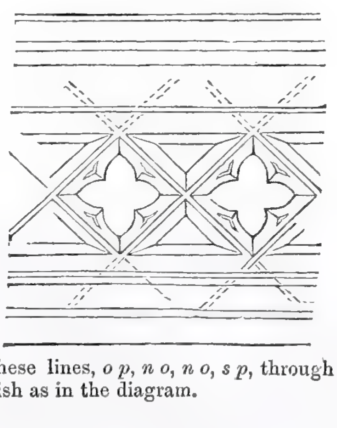
Bisect the sides, *a d c b*, as in the point *e*. The points thus obtained will correspond to *a*, *b*, *d*, *c* in the diagram to the left. With radius, *b e*, from the points, *b*, *c*, *d*, *a*, describe arcs meeting the lines, *b a*, *a d*, *d c*, *c b*, in the points of bisection. The internal circles of the diagram will thus be obtained. In the diagram to the left, the points *e f* correspond to *b c*.

Fig. 117.



In fig. 117, to the left, we give a square panel. Construct a square, *e f g h*, equal to *a b c d*; draw the diagonals, *g f*, *h e*, and

Fig. 118.



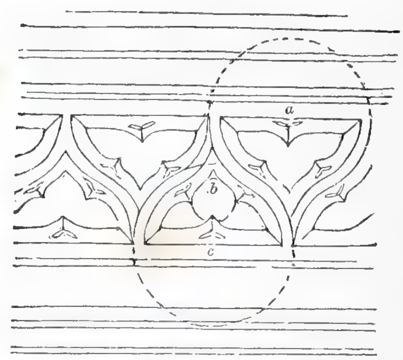
parallel to these lines, *o p*, *n o*, *n o*, *s p*, through the corners, *e f g h*. Finish as in the diagram.

The pupil having mastered the rudimentary lessons thus presented him, may now proceed to the delineation of more intricate subjects.

Fig 119.

From figs. 118 to 121, inclusive, we give drawings of perforated parapets in various styles of Gothic architecture. These,

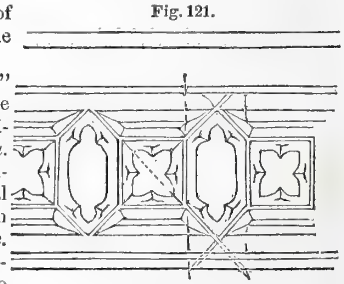
Fig. 120.



although apparently much more difficult of construction than the simple diagrams with which we have presented our readers as introductory to this department, are not in reality so. Thus, in fig. 118, a series of squares form the whole design. Again, in fig. 121, the alternate squares and pointed oblongs are drawn.

From the "rules" given in the other examples, the pupil will be able to delineate them to any scale or size required, the same size as in the sketches, or twice the size, which latter would be better than the former for the purpose of seeing more easily the operations necessary.

Fig. 121.

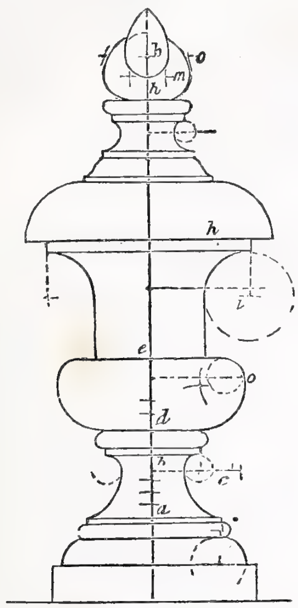


To delineate the "vase" in fig. 122. Put in the plinth and bottom mouldings up to the point *a*. Measure from *a* to *b*, divide *a b* into five equal parts. Through the fourth of these draw a line to *c*. Put in the fillet at *b*; produce the end of this to cut the line *b c*. Put in the bead at *d f*. Measure from *d* to *e*, and divide it into four equal parts. From the fourth of the points on *d e*, as *p*, measure to *o*, a distance equal to *e f*. From *o* describe an arc, meeting a line produced through *e*, and cutting *p g* in *g*. From *f* and *g* as centres, with any radius greater than half the distance between them, describe arcs cutting in *h*. From *h*, with *h g*, describe the arc *g f*. The other centres are marked.

To delineate the vase in fig. 123. Divide the height, *a b*, into sixteen equal parts. From the fifth of these, with 5 2 as radius, describe an arc, 2 *x*. Through the tenth point, draw

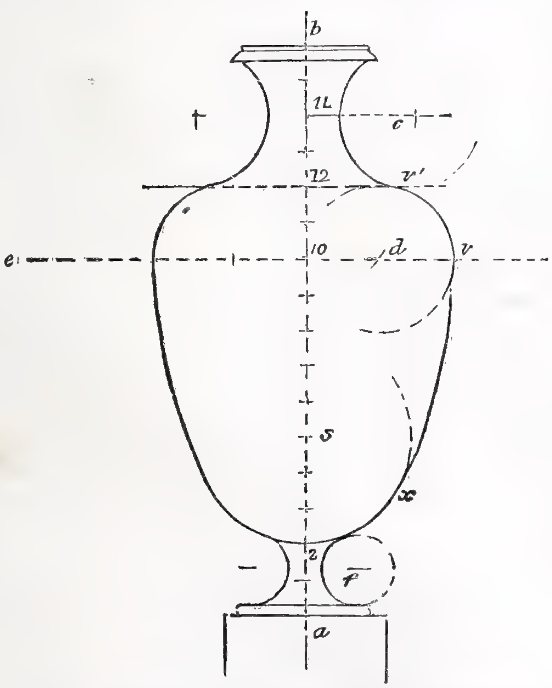
a line at right angles to $a\ b$, as d, 10, v. Take two of the divisions, and lay it from 10 to d. From d, with $d\ v$ equal to 10 d, describe a quadrant, $v\ v'$, cutting a line drawn through the

Fig. 122.



twelfth point parallel to 10, $d\ v$. Through the fourteenth point draw a line 14, c. Set off three of the divisions on $a\ b$ from the point 14 to c; and with $c\ v'$ as radius, describe a semicircle as in the diagram. From the point 10 set off ten divisions to

Fig. 123.

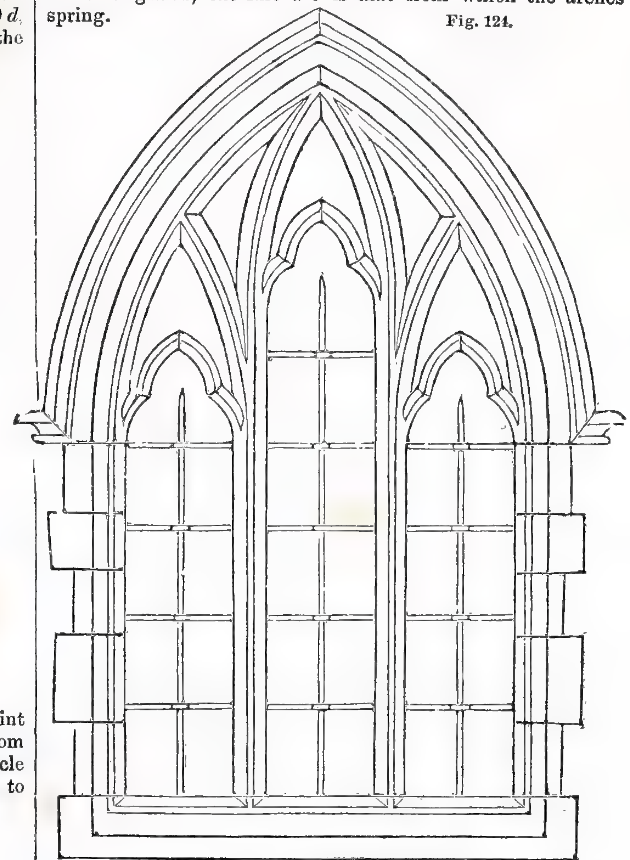


the point e. From e as centre, with $e\ x$ as radius, describe the arc $x\ v$.

In figs. 124, 125, we give elevations of Gothic windows.

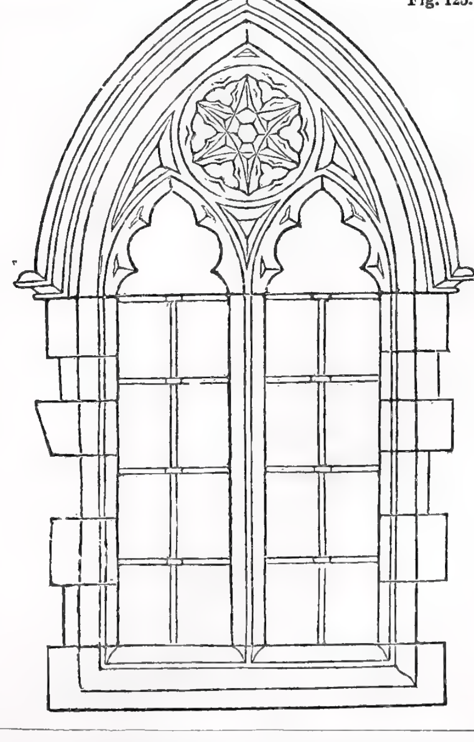
In figs. 126 to 132 we give a series of analytical diagrams, showing the method of delineating the above examples. In these diagrams, the line $a\ b$ is that from which the arches spring.

Fig. 124.



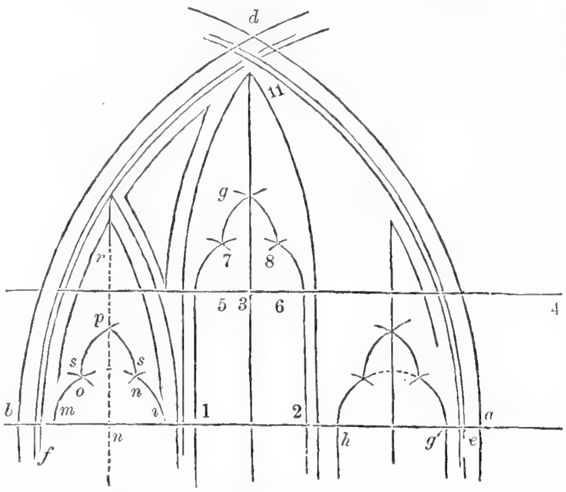
To delineate the window-head in fig. 124. Draw the lines $a\ b$, $c\ d$, fig. 126. From c measure to $e\ f$; from these points as

Fig. 125.



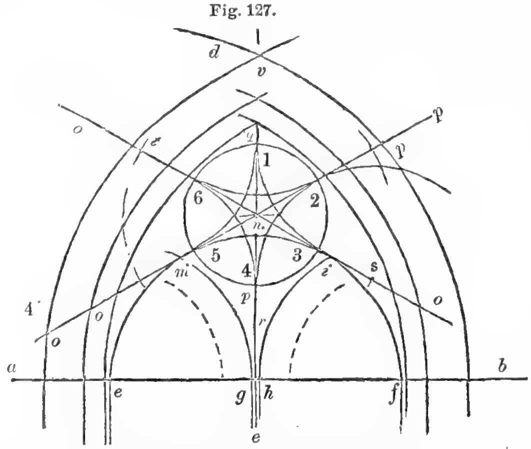
centres describe, with radii $e\,b, f\,a$, arcs cutting in d. Measure from e to g, and from f to m; set off towards c the width of small arches to i and h. Bisect $i\,m$ in n', and from n', with $n'\,m$, describe a semicircle; from i and m', with same radius, $n'\,m$, cut this in the points, n and o; from these describe arcs, with same radius, cutting in p. Draw $n'\,p\,r$. From e, with

Fig. 126.



$e\,r$, draw an arc, $r\,s$, and from t on $a\,b$, produced with $t\,r$, as radius, one arc, $r\,v$. From c set off to 1, 2, and 3; through 3 draw a line parallel to $a\,b$; draw 1, 5, 2, 6 parallel to $c\,d$. From 3, with 3, 6, describe the same circle, 5, 7, 8, 6. From 5, 6, cut this in 7, 8, and from these points, 7, 8, with same radius, describe arcs cutting in the point 9. From the points, 4 4', as centres on the line, 5, 3, 6, produced with radii, 4 a, 4' b, describe arcs cutting in the point 11.

Fig. 127.



To delineate the window head of the example in fig. 125. Draw $a\,b$, $c\,d$, fig. 127. From $e\,f$, as centres, with $e\,b$, $f\,a$, as radii, describe arcs cutting in d. From c measure to n, and from this point describe the circle. Divide this into six equal parts, and through the centre, n, draw through three lines, $o\,p$, $r\,v$, $t\,s$. From s, r, o, t, v, and p, describe the arcs in the circle, n. From $e\,g$, $h\,f$, with radius, $h\,f$, describe arcs cutting in $m\,i$.

THE MACHINERY OF THE COTTON MANUFACTURE.

CHAPTER VII.

Having in last chapter described the movements of the roving frame, we propose now to notice the next machine, the "throstle;" previous to which, however, we give a brief description of the roving and slubbing frame of Mr. Mason of Rochdale, of which we give a plate, showing a front and end elevation drawn to scale. The general framing is shown at $b\,b$, motion being given to the main driving shaft through the fast and loose pulleys, $c\,c$. The bobbins are shown at $a\,a$; the flies at $f\,f$; $d\,d$ the drawing rollers. The bobbins, $a\,a$, are produced by a coarse roving frame, the movements of which we have in last chapter described; from those large bobbins the presser bobbins, with conical ends, are formed by the mechanism described in figs. 13 to 17 in last chapter. In the coarse drawing frame the cotton is passed to the drawing rollers from the tin cans.

Mr. Mason has introduced an improvement in roving frames, which we now describe. The object of this improved frame is to give a firm support to the spindle, and thus to obtain a higher degree of speed, and a greater amount of work. This is effected by making the ordinary collar in the lifting rail longer, continuing it through the pinion-wheel up the inside of the bobbin band to its top, forming the bearing of the spindle at this point. The increased action observable when the bearing is low, is obviated by this arrangement.

In order, however, to reduce the friction as much as possible, the collar is made with a hollow chamber or recess in the inside, so that the spindle fits only at the end. The bobbin is also prevented rubbing upon the outside of the collar by its being made to fit upon a flange at its lower end, projecting from the top of the pinion-wheel. By this arrangement a difference is obtained in favour of the new plan of a lift—if equal to the length of lift—say equal to ten inches in coarse, and seven in fine roving frames. The collar is a fixture, firmly screwed down to the lifting rail for steadying the spindle at its upper end, and the pinion-wheel and bobbin run loosely round it. The bobbins are made to pass over the junction of the spindles and flyers, so that one inch longer lift is obtained in the same length of flyer. The improved spindles are working at the following speeds: slubbing, with twelve inch lift, 100 revolutions; ten inch lift, 800; intermediate, eight inch lift, 1,000; roving, six and seven, from 1,200 to 1,400.

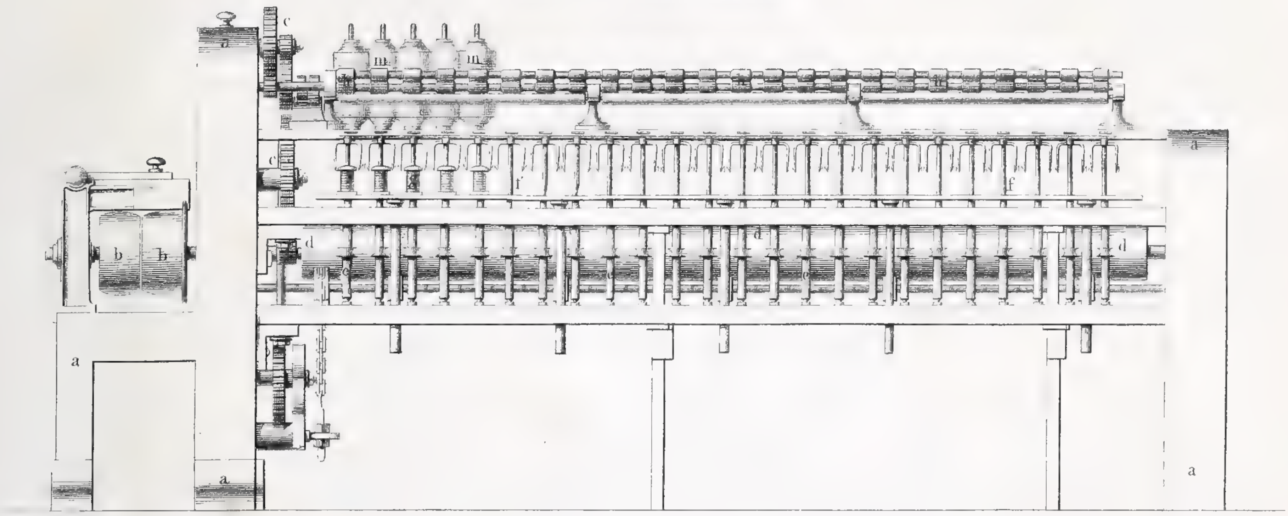
The "twist" which the roving machine gives to the cotton is not designed to be permanent; but is simply required in order to enable the yarn to be wound evenly upon the surface of the bobbin. When we consider that the first operation the succeeding machine—the throstle—has to perform, is to "draw" the fibres by passing them between drawing rollers, it is evident that, if much twist was imparted by the roving frame, this drawing in the throstle would be greatly prevented.

The operations of the throstle resemble very much in character those of the roving frame; the mechanism, however, being of a much more simple kind. The difference between the speed of the bobbin and the "fly" is not obtained with such complicated mechanism; this being effected simply by what is called the "drag" of the former upon a flannel surface placed upon the "copping rail." By the friction thus caused, the speed of the bobbin is lessened, while that of the flyer and the drawing rollers remain uniform—the result being the same as in the drawing frame. Of course the same accuracy of adjustment is not attainable as in the drawing frame; this, however, is not necessitated, as from the greater amount of twist which the fibres in the throstle receive, all the yarn is enabled to exert a sufficient drag, to regulate with some degree of efficiency the retarding of the speed of the bobbin in proportion to its increase of diameter.

We now proceed to detail the various parts of the mechanism, as exemplified in the three views which we give, and for the drawings of which we are indebted to John Mason, Esq., machine maker, Rochdale. The yarn from the bobbin of the roving frame passes through the drawing rollers, h; and from these to the bobbins, g. As the yarn, if always passing over the same part of the delivering roller, would soon cut its surface, it is made to pass to and fro over the whole length by the following mechanism:—The yarn, in passing to the delivery rollers, goes through a series of eyes fixed vertically in a horizontal bar, placed behind the series of delivery rollers; to this a lateral movement is given. This is effected by an endless screw

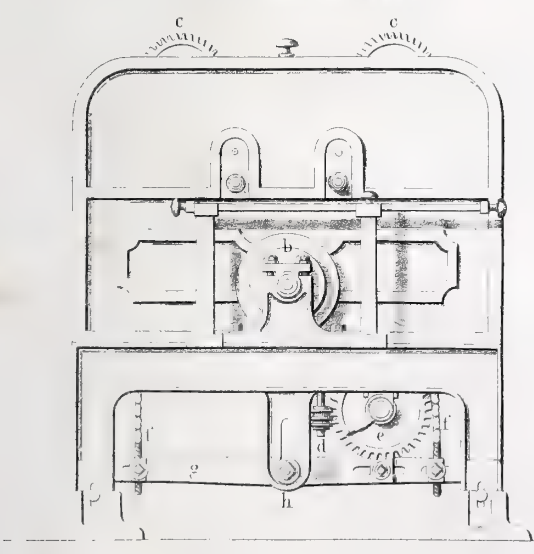
THROSTLE COTTON

FRONT ELEVATION.

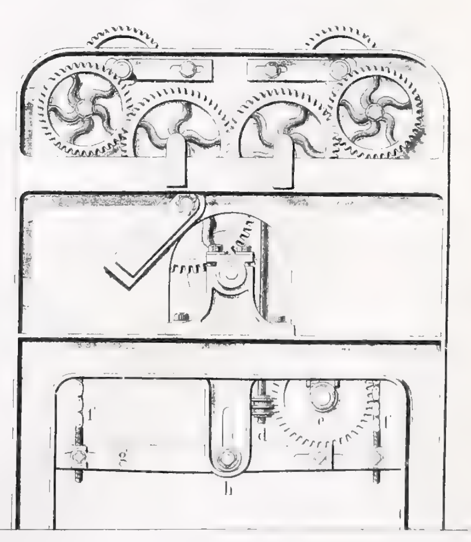


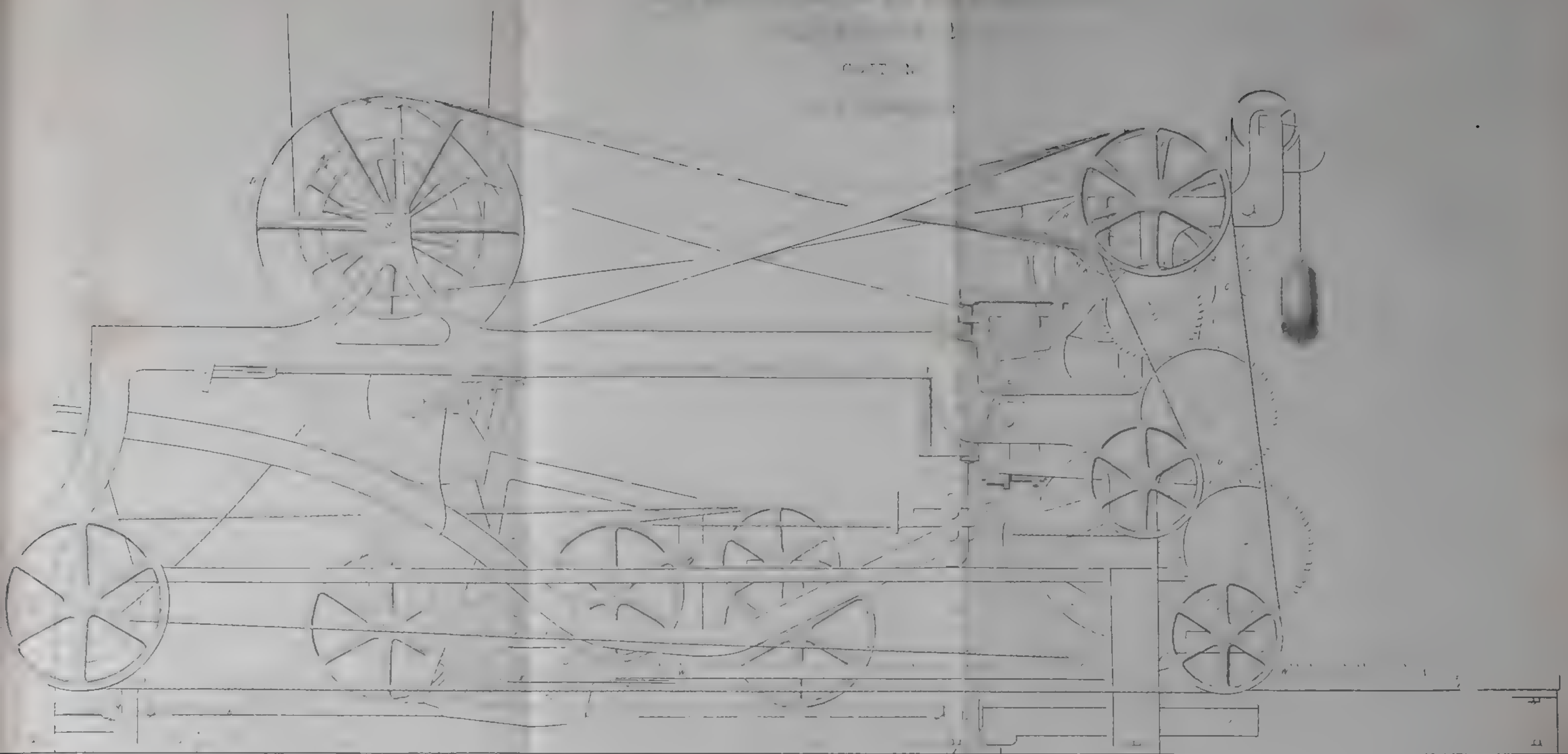
SCALE ¾ INCH = 1 FOOT

END ELEVATION



END ELEVATION





SCALE

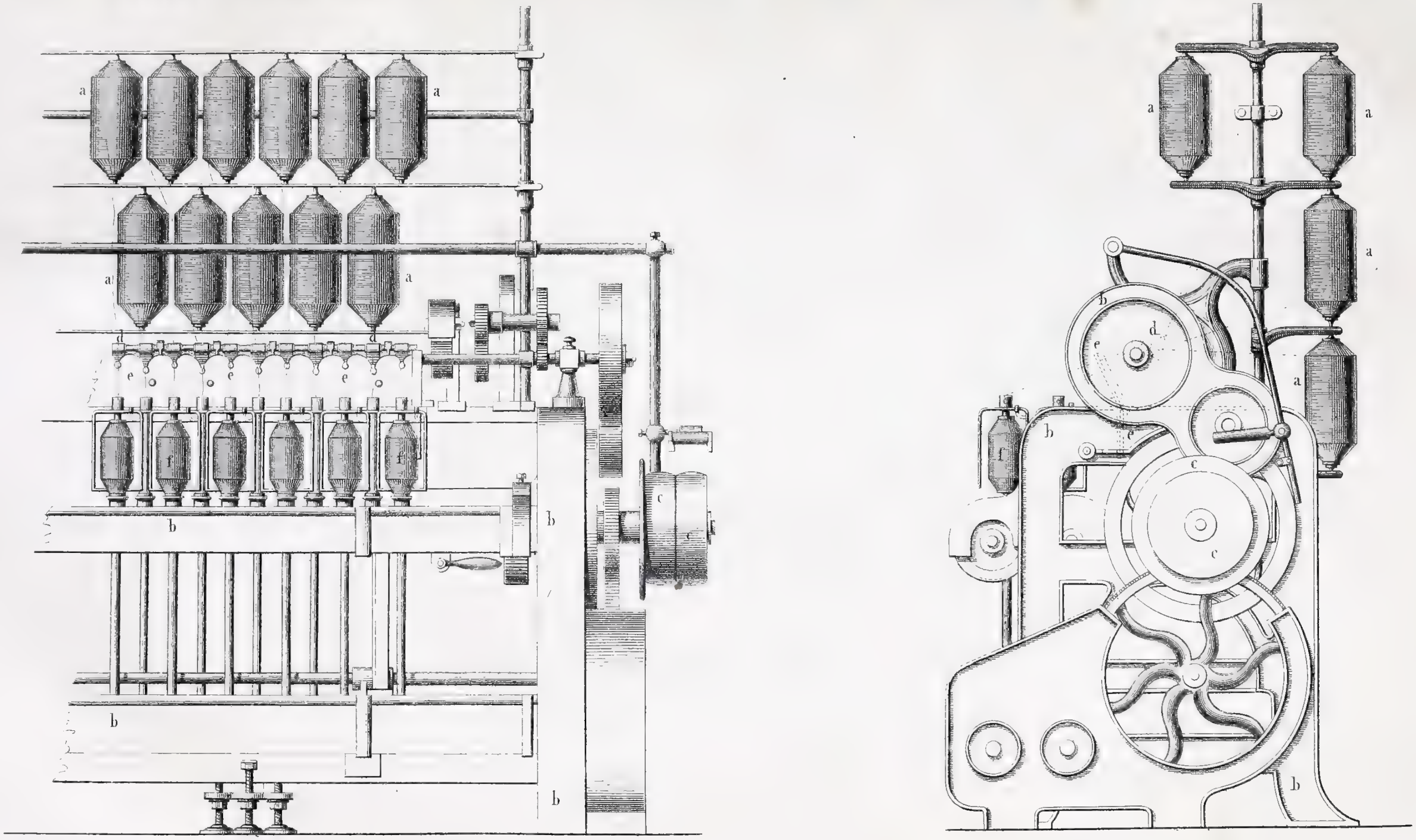
MASON'S

PATENT ROVING or SLUBBING FRAME

FOR SOFT OR PRESSER BOBBINS

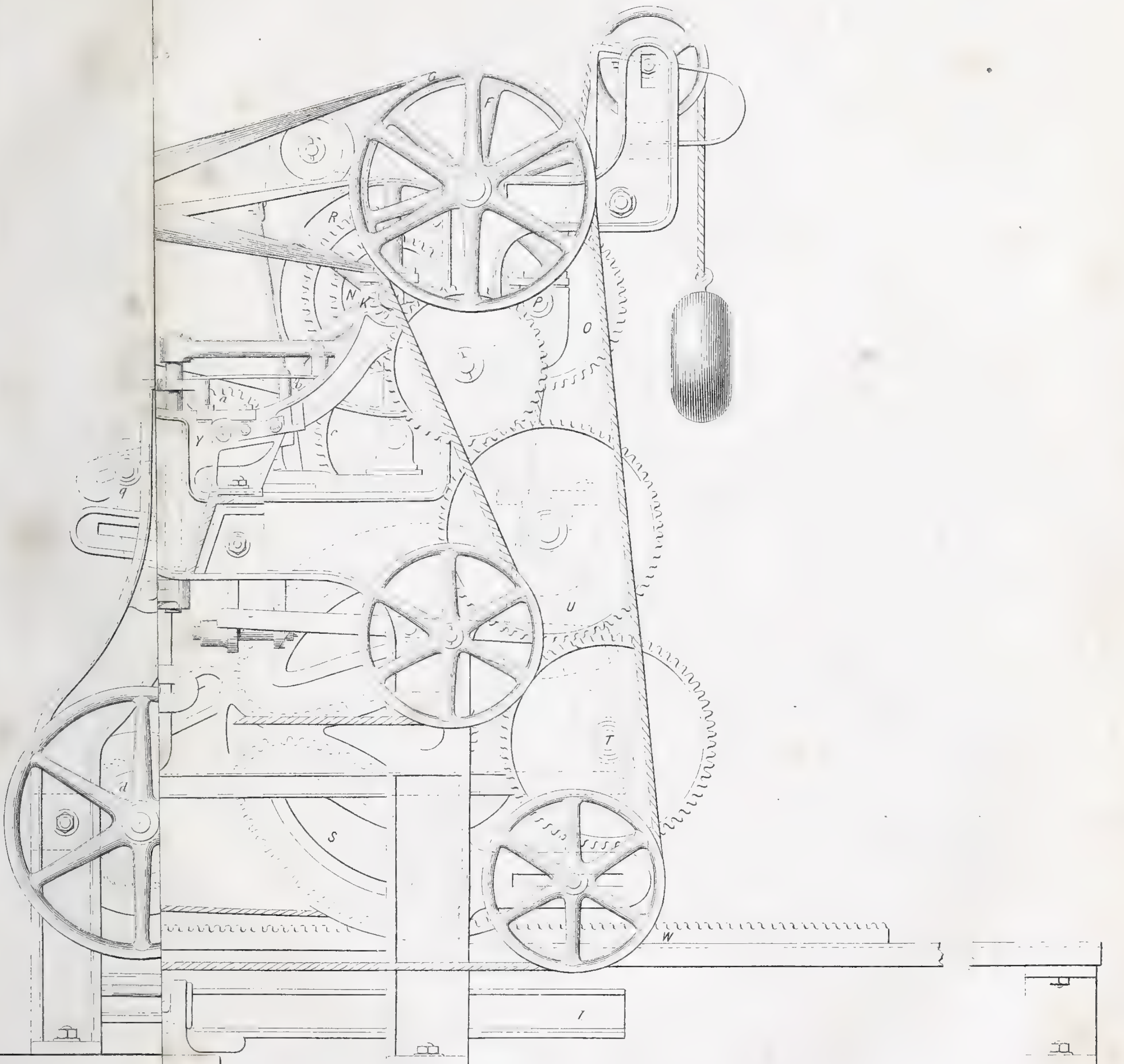
FRONT ELEVATION.

END ELEVATION



SCALE ¾ INCH = 1 FOOT.

ᶜ GREGORS.



fixed in the extremity of the back roller shaft, taking into a small toothed wheel. On the face of this, at some distance from its real centre, a pin is fixed, to which is connected a small rod or lever, the other extremity being jointed to a stud fixed on the end of the horizontal bar above noted. As the face wheel revolves, a to-and-fro movement is given to the bar, the consequence of which is, that the yarn passes from one point to another of the leather surface of the delivering roller, and a regular wear effected.

The bobbins upon which the yarn is wound rest upon the copping rail, which extends the whole length of the machine, and revolve on the spindles which support the fly. This is capable of being easily removed to admit of the bobbins being "stopped" when full. The bobbins and fly are very light and small compared to those of the roving frame, and in all cases the bobbins have ends. The spindles are made to revolve by a band passing round a small pulley or "warve" placed on their lower ends; this band passing round a drum, *d d*, in the centre of the machine, this is set in motion by the train of wheels, *c c*; *b b* being the fast and loose pulleys. The laying on of the yarn on the surface of the bobbin is effected by causing the copping rail on which they rest to rise up and down by mechanism as follows—illustrated in the end elevations on the plate:—The shaft of the worm *d* receives motion from another worm at its upper extremity, into which a toothed wheel gears The worm *d* moves that of *e*, on the side of which a heart-shaped wheel is fixed. This revolves in contact with a friction-wheel placed on the lever, *g*, the centre of vibration of which is at *h*. The up and down motion of this, resulting from the action of the eccentric heart-shaped wheel, is communicated by means of chains, *ff*, to a pulley fixed on the end of a shaft, which extends the whole length of the machine. The copping rail is supported by bars, and is moved up and down by the action of the pulley and chain, which have an alternate motion produced as already described. This "traverse motion is uniform, not varying as in the roving frame; but, from the greater firmness of the yarn, this is not a matter of much consequence, the only result being that, as the bobbin gets enlarged, the yarn in its convolution is placed wider apart on its surface, the same quantity of yarn having to be delivered round a greater surface; just as a given length of thread being wound round a large roller from top to bottom, may be just sufficient to form a single helix or screw-like thread; while the same quantity on a roller of much less dimensions, may have its convolutions or windings very close to each other."

The machine we have next to describe is the "mule." We have shown how the "throstle" has for its duty the winding of the yarn upon the bobbins. These are afterwards taken to the "warping mill," and prepared for the loom. The throstle yarn is almost invariably used for the "warp" of the cloth; that is, for the portion which stretches longitudinally along the loom, or in the direction of the length of the cloth. The yarn, however, of the "mule" is used for the "weft," or those threads which stretch across the cloth, although it is used sometimes for both warp and weft. The yarn in the mule is not wound round bobbins, but "built" upon a central tube or spindle, in a conical form, gradually tapering to a point. The motions of the "self-acting mule" are very complicated; but, in order to enable the reader to understand them, as illustrated in the plates which we gave of Messrs. M'Gregor's mule, we deem it best to give a short account of the "hand mule." A mule consists of two distinct and characteristic parts—the "headstock" and the "carriage." In the former are contained the "bobbins" from the roving frame, which are placed on spindles to allow of their easy revolution; and the "drawing rollers," which draw out and elongate the yarn as it is delivered from the bobbins. The "carriage" contains the spindles round which the fine yarn is to be wound—this is capable of being moved to and from the "headstock" on a small railway; and the spindles are set in motion by a band passing from a central drum round "warves," fixed at the ends of the spindles. In commencing operations, the carriage is drawn out from the headstock at a quicker rate than the drawing rollers revolve, so that the yarn is still further drawn or attenuated; as the carriage reaches the end of its draw, some fifty or sixty inches, the drawing rollers cease to give out the yarn, the velocity of the spindles is increased, and thus the twist is imparted to the yarn. At this stage the carriage is disconnected with the machinery which draw it out, and the operations are finished by the "mule spinner." The yarn in its way to the spindles passes over a "wire," termed the "faller" or "copping wire:" this he depresses, so as to place the yarn at the bottom of the "cop;" at the same time he causes the spindles to revolve backwards, in order to disengage that portion of the yarn which had wound itself round the upper extremity of the spindle—this he does by turning the drum which drives the spindle the reverse way. When these movements are finished, the spinner turns with one hand the drum, which moves the spindle in the right direction, pushing in—"towards the headstock"—the carriage at the same time with his knee, regulating its rate of motion so as to supply the yarn as fast as the spindles take it up. Towards the end of the "run," he raises the "faller wire," so as to cause the yarn to be wound round the spindle of a gradually smaller diameter. The operations the spinner has to perform are thus three, and all of them at the same time, and regulated in proportion to each other: first, the manipulation of the faller wire, so as to insure the regular laying on of the yarn on the spindle; second, the moving in of the carriage; and, third, the turning of the drum which gives motion to the spindles. These make the mule-spinner's occupation, one requiring his continual attendance, as well as the outlay of considerable bodily strength. In the self-acting mule, all these operations are performed by machinery alone; the only manual labour desiderated, being that of "piecing" up or mending such of the yarns as happen to break.

In the two plates of M'Gregor's self-acting mule, we give a plan and elevation drawn to scale; they illustrate a machine capable of working with ease 1,000 spindles, spinning (thirty-fours) 34 hanks to the pound, warp or weft, at four draws per minute.

Fig. 1 represents a side elevation of the mule headstock with carriage end. Fig. 2 is a plan of the same, showing the carriage ends on each side of the headstock, and part of a carriage. A A are the driving pulleys, for driving the whole machine direct for a pulley on the main mill gearing, the one pulley being fast, and the other loose; B is the rim-shaft, which should revolve about 240 revolutions per minute; C is the pulley for driving carriage and rollers; and D the "rim" for driving the spindles; E is the spindle motion shaft, on which is placed the fast and loose pulleys, F F; G G are the twist pulleys, which are changed if the speed of the spindles is wanted to be altered; H is the brake pulley, for stopping the spindles when done twisting the yarn; J is the carriage motion shaft, on the end of which is placed the pinion, K, for driving the carriage and rollers. This pinion is changed when the twist of the yarn wants to be altered, without altering the speed of the spindles, and is called the "slubbing pinion." L is a fast pulley on the shaft, J, for driving the carriage; M is a loose pulley on the same shaft, on the boss of which is the wheel, N, which gears into the wheel, O, fast on the shaft, P; the wheel, Q, is also fast on the shaft, P, and gears into the wheel, R, fast on the carriage shaft, J. The loose pulley, M, with its train of wheels, is for giving a slow motion to the carriage, in the proportion of about 3 to 1 for the last few inches of the stretch when spinning twist, instead of standing and twisting at the head, as is the usual way in hand mules. S is the mangle-wheel, which gives the alternating motion to the carriage, and is driven (through the train of wheels from the slubbing pinion, K) by a pinion, with ten teeth on the end of the shaft, T (this pinion is not seen in the drawing, as it works internally in the mangle-wheel, S). The shaft, T, runs in a socket on the end of a swing, U, and by that means is allowed to go for the outside of the mangle-wheel to the inside, and thereby change the motion of the carriage. The mangle-wheel communicates motion to the carriage by the spur-wheel, V, cast on the outside of the mangle-wheel, and which gears into the rack, W; this rack, being fast to the cross piece, X, which pins the carriages on each side of the

headstock, Y, is the first roller which is driven from the spur-wheel, V, on the mangle-wheel, through a train of wheels to bring up the speed, three of which, *a*, *b*, *c*, are only seen in the drawing. Either of these wheels are changed, if the speed of the rollers in relation to the speed of the carriage requires changing, or if more or less "gain" is required in the yarn. The remainder of the roller apparatus is not shown, as it is the same as in the ordinary hand mules. The winding-on band is shown at *d*, a ratchet-wheel being cast on this. This ratchet-wheel, when winding on the yarn, drives the pulleys, *e* and *f*, through catches in the plate of the wheel, *e*; in this way, the motion is communicated to the spindles. When the yarn is being twisted, the catches in the plate of the wheel, *e*, keeps out of gear of the ratchet-wheel on the band by centrifugal force. Plates, *g*, *g*, are screwed to the floor, to which are attached the builders for building the cops. The builder screw is at *h*, on which is fixed the ratchet-wheel, *i*, a tooth of which is taken up every draw. According as the cops are desired to be larger or smaller, this ratchet-wheel has to be changed. The stripping plate is at *j*; the office of this is to strip the coils off from the spindle previous to building the cop. This, as will be remembered, is accomplished in the hand mule, by turning the spindles in a reverse direction—this being also done in some forms of self-acting mules. A catch-box is at *k*; it is placed in the middle of the carriage, and is driven from the rack, *i*, cast to the first carriage slip; this catch-box is thrown into gear when, from the yarn being too tight in winding on to the cop, the under faller wire is pulled down one inch below the spindle point; and through the train of wheels seen in the drawing, gives motion to the screw in the radial arm, *n*, and raises the nut, to which is attached the "winding or chain." By this means the yarn is slackened in winding on, until the under faller wire rises so far as to throw the catch-box out of gear. A connecting-rod for working the faller wire is shown at *o*; this is actuated by the lever, *p*, attached to the carriage ends. One end of the rod is attached to the swing, U; and as the pinion on the end of the shaft, T, travels from the outside of the mangle-wheel to the inside to take in the carriage, the lever, *p*, is acted upon from a pulley on the end of the lever, *q*, and thereby works the fallers preparatory to building the "cop." When the carriage goes towards the headstock, the end of the screw, *r*, strikes the lever, *p*, and raises the fallers. *s* is an inclined plane attached to the framing, for causing the radial arm to describe an arc of a circle every "draw."

This form of self-acting mule is now being largely used; Messrs. M'Gregor having fitted up a great number of them for the first firms in Lancashire.

BUILDING ARTS.

CHAPTER VIII.

Having, in last chapter, discussed the question of size, we now proceed to that of shape, of the drains.

Experience, as well as theory, points out the circular form as that best adapted for channels in which fluid is designed to flow. Where the surface with which the water comes in contact is reduced, the friction is also reduced, and the flow is quickened. Now, it is well known that the circle includes within its perimeter or outer boundary line a greater area than any other figure; so that, while containing space to hold a larger quantity of water, it possesses less surface than a tube of any other shape would; in other words, the proportion of surface of channel is small, compared with the quantity of water flowing through it. The following remarks by Mr. W. Templeton will show the principles upon which the practice of having circular drains is founded: "Water, in flowing through an orifice or aperture under any given head (*i. e.* pressure), is governed by the same laws of gravity as that of a solid body *in vacuo*, descending through the same space, or falling from an equal height; but as friction is increased by the motion of two hard bodies in contact, so is friction also created by the action of water in passing through an orifice or aperture: hence an aperture twice the width of another will discharge more than a double quantity, because of the area advancing in a much greater ratio to that of the resistance. Thus, suppose an opening of four square feet required in a circular form, its diameter would be two feet three inches, and its circumference, or cause of friction, seven feet; in a square form two feet by two feet, and the amount of its sides eight feet; but in a rectangular form, four feet in length and one in breadth, the cause of resistance is increased to ten feet, thus showing that the circular form is that which ought to be adopted in preference to any other for the conduction of water where practicability will admit." Mr. Roe, an engineer of large experience in drainage matters, states that with the flat-bottomed drain, as compared with the circular, the deposit, from the increased sluggishness of the flow, is more than one half greater in amount. "It is quite certain," says Mr. Hosking, "that the same quantity of water will carry over a quickly curved bottom substances which would remain if less curved. It confines the water where there is small quantities, so that it may act upon the substances that pass into the drain with most effect; and it gives an increased space to the water as the water increases in depth." This latter part of the sentence has reference more particularly to the egg-shaped drain, which has the lower end of a smaller radius than the upper.

Viewing these principles as the correct ones, the inefficient construction of the form of drain, shown in fig. 1, will at once be seen. Where bricks are used to construct a drain of such

Fig. 1.

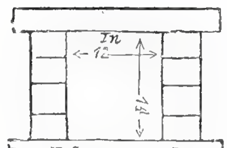
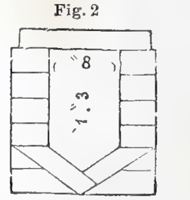


Fig. 2



small dimensions as to make a circular bottom a matter of some expense, the form shown in fig. 2 may be adopted. But for small drains—see our former remarks on the maximum of size to be adopted—no better form, and no more durable material, can be obtained than the circular tubes made of glazed earthenware.

In laying earthenware drain tubes, great attention should be taken to make the joints perfect. To insure this, they should be bedded in well-puddled clay, and the joints luted with the same. There are various methods in use for effecting a water-tight joint. The "socket" joint is a well-known form, and does not require illustration here. After making the joints of two or three lengths, a wooden plug with an iron rod should be passed through the tubes, to free the interior from adhering clay pressed through the joints in forming them. The pipes should not have a bearing on the sockets merely, but as much as possible along the whole length of the tube. Drain tubes are sometimes joined by means of the "rabbit joint," as in fig. 3; with the conical joint, as in fig. 4, they are perhaps mere efficient. In one drain tube, patented by Mr. Clayton, one end, as shown in fig. 5, is bored or cored out, while the other is turned down to fit into this.

Fig. 3.

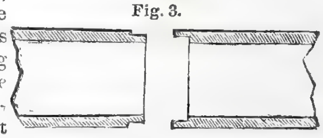
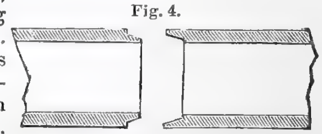


Fig. 4.

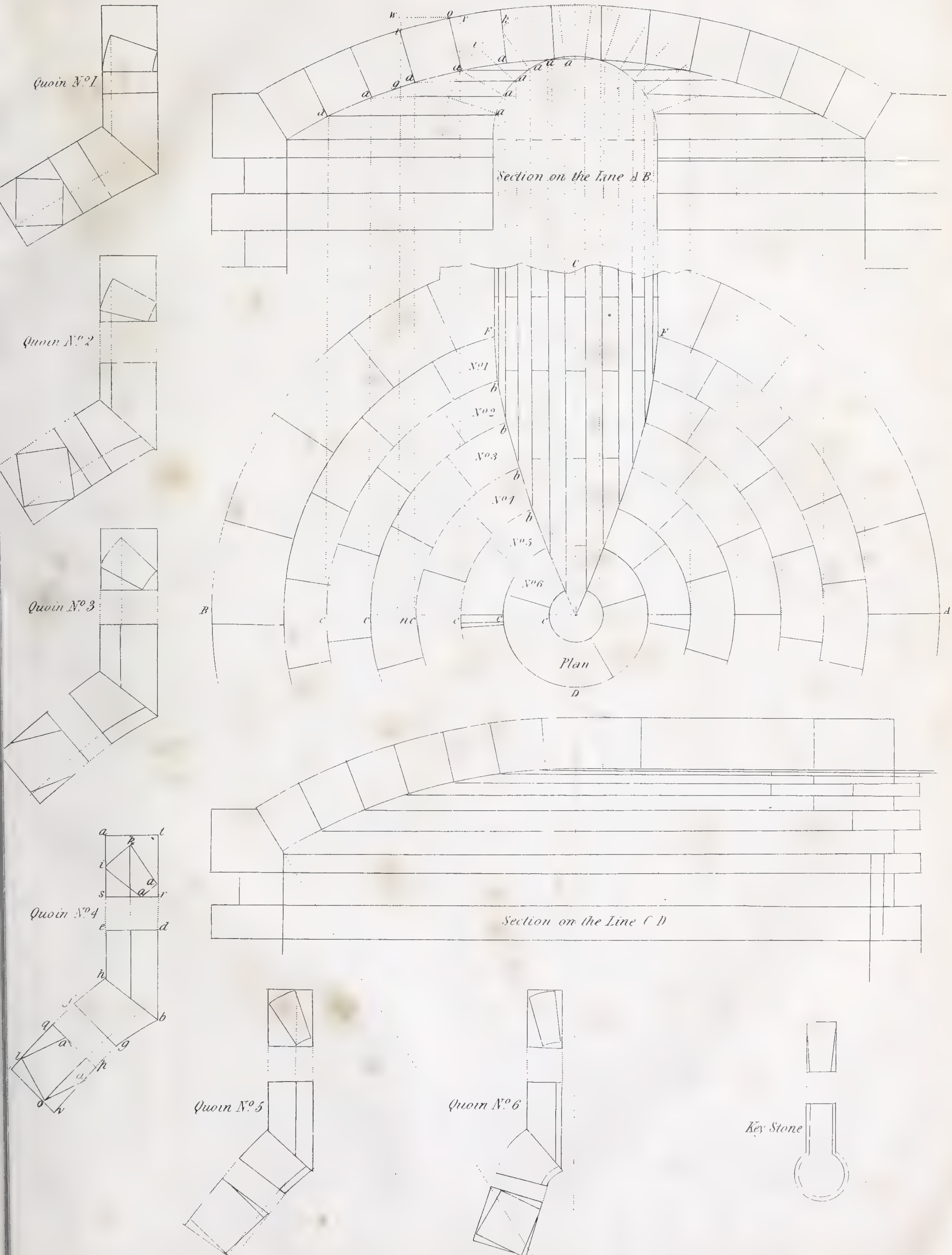


It has long been a desideratum in tube-laying, to have some ready method of taking up a length which has by some accident broken, without disarranging several of the tubes, as must be the case with the form of joints we have noticed. An attempt to attain this has been made by Mr. Austin in his half socket joint, illustrated in fig. 6; this he proposes to be manufactured either with a half socket, at one end only of eac!

PLATE B

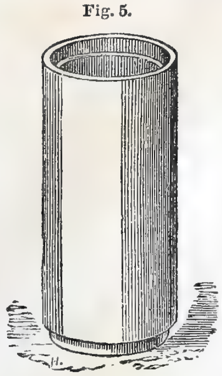
RKING DRAWING

Arched Groins



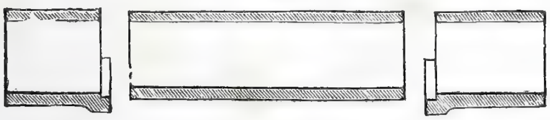
length, or at the lower half of both ends, to be used alternately without any socket. "The advantage to be derived from this arrangement is, that the half sockets form a bed in which the plain pipes are laid, not pushed in, as in the socket pipe; thus every joint as it is made is open to inspection; and, in case of accident or faulty joint making, any one length of pipe can be taken up without disturbing the others."

Fig. 5.



In forming junctions, great care should be taken not to have them at right angles—this most certainly impedes the flow of the drainage liquid. It has been ascertained, that where resistance due to a junction at right angles was 316, that due to a curved junction of five feet radius was 146, while that for a curved junction of twenty feet radius was only 100; thus proving the resistance to be 200 per cent. over the junction of twenty feet radius. Figs. 8 and 9 illustrate forms of curved junction. The pipe joining should enter the joined pipe, if possible, near the bottom, not in the centre of the tube—this is found to exercise a beneficial influence on the flow.

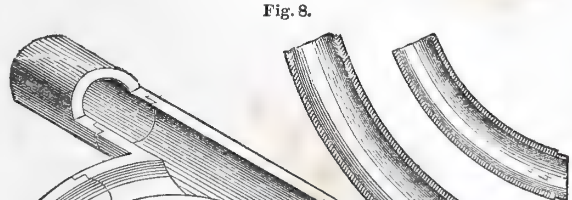
Fig. 6.



In laying the tubes, a gradual fall should be given to the whole sides throughout their length—one in twenty will in most cases be sufficient; it, however, cannot be too great, as the greater deviation from the horizontal, the quicker will be the flow.

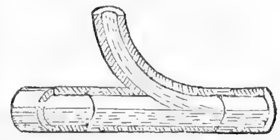
The entrance to all drains, either external or internal—the latter, however, more especially—are generally trapped, in order to prevent the "gaseous" products from gaining access to the house, &c., from their interior. In all the great varieties of forms introduced, the principle is the same. "An exit aperture is made at such a level that the liquid always remains to cover that part of the trap round which the foul air must necessarily go, before ascending the trap; thus the ascent of all deleterious gases is prevented, so long as the trap is kept supplied with water, and the solid deposit prevented from accumulating in too great a degree." It has been generally supposed that the forms of water-traps on this principle—as that illustrated in fig. 10, known as "Jennings'" trap—formed safeguards against the entrance of foul gases from the entrance of the drain, to the place in which the trapped entrance might be, as in a water-closet. Recent inquiries, however, into the

Fig. 8.



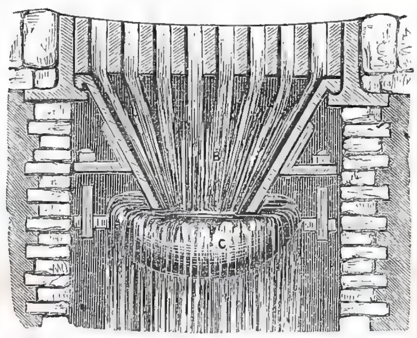
Croydon fever, as it was termed—arising from defective drainage—instituted by Government, have rendered it extremely doubtful whether they really are so. On the contrary, it appears from the investigation of Dr. Arnott, one of the commissioners appointed to inquire into the matter, that they too often act as a medium for introducing foul air into apartments. The following are Dr. Arnott's remarks on this point, which, from the importance of the principles involved, are worthy of the most earnest attention of all those connected with the building arts:

Fig. 9.



"This sudden emission of foul gas through the siphon trap, supposed to be secure, of a drain, into which water readily enters and passes along, being somewhat paradoxical, has by many persons not been understood, and so not guarded against. The explanation is this: If into the neck of a bottle half full of water the stalk of a funnel be passed, and some water be poured into the funnel, then just the same air must escape round the

Fig. 10.



stalk of the funnel as there is of water entering; the air being pressed out or displaced by the descending water. If the funnel stalk be then covered so as to fill the neck of the bottle like a cork, the descent of the water is either totally obstructed by the resisting air below, or the water descends only gradually, as bubbles of air rise up through it. The air thus compressed in an air-tight cavity by the weight of water seeking to occupy its place, would escape by any small opening which it might find; just as coal gas escapes from such a compression made at the central gas-works, through the aperture of gas burners. In a sink or water-closet, with a drain entirely stopped by any solid plug, it follows that the air shut up between the entrance and the stoppage is situated like the air in the bottle described above, and must be compressed or driven out by water entering; but the same may happen if the solid stoppage be only partial; that is to say, such as will allow water to pass by, only less quickly than it enters above; or if the stoppage be not by a solid obstruction at all, but merely by water detained in a part of the drain, which either by original fault of the laying down, or by subsequent accidental subsidence in yielding earth, has sunk below the

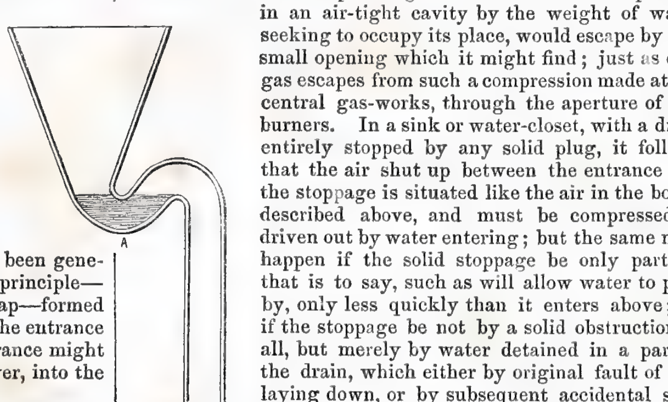


Fig. 11.

proper line of the drain, as represented in the accompanying diagram (fig. 11). In the last case, it is evident that the siphon trap of the closet-pan at A, shutting in the foul air between A and B, has less depth or resisting column of water than the accidental trap at B, and that air compressed between these will more easily force its way at A into the closet and house than at B, along the drain towards the rainfall. But even in cases where the drain does not subside, as in fig. 11, the fluid generally remains in such a position in the tubes that a space is left between "the trap" at the closet or sink and the

water in the drain, in which the gases accumulate, these necessarily escaping by the trap at the closet each time water is thrown down, the quantity of gas escaping being in proportion to the water descending; thus "the closets and motors are the ventilators of the sewers, and the dwellings the receptacles for their poisonous contents." But even where the above conditions of the drain are not existent, but the connection between the trap at the closet and the drain properly made, the trap will not act; for, in many instances, the accumulation of gases in the drains may produce a pressure sufficient to overbalance the weight of water in the trap, and thus escape.

The only remedy for the state of matters we have described is the ventilation of the drain. This is done very efficiently by carrying a pipe or tube from the drain in the immediate neighbourhood of the water-closet or sink, to the level of the roof. This, which has hitherto been totally neglected, must hereafter be attended to, if immunity from the evil effects of foul air forced from drains into houses is desired. Where the points in construction and laying of drains we have pointed out are attended to, and the additional precaution of ventilation secured, a system of drainage, comparatively perfect, may be looked upon as secured.

THE ALHAMBRA.

Who has not heard of the Alhambra (or "the red castle"), a name given to a fortress in Spain, within which was the celebrated palace of the ancient Moorish kings of Grenada? The palace of the Alhambra was commenced in 1248 by Ibnu 'l Ahmar, continued by his son Abu Abdillah, and finished by his grandson, Mohammed III., about 1314. It was regilt and painted by Yusuf I. in 1348. Its ancient magnificence was unparalleled, and the accounts of it read like the visions of oriental fiction; but it has, in the course of centuries of neglect, fallen into such a state of dilapidation, that the visitor can form a very inadequate idea of its original splendour.

Thanks, however, to modern art and skill, and the assiduous and intelligent labours of Mr. Owen Jones, the glories of the Alhambra have been revived in the Crystal Palace of Sydenham, that magnificent museum of the works and wonders of all ages and all climes. The curious can now visit the Alhambra without leaving England. The Moorish palace has been imported, its principal and characteristic features have been reconstructed, and the Alhambra court now constitutes one of the most attractive compartments in the Crystal Palace. We do not speak of it as a mere spectacle gratifying to the senses, but as a revived record and monument of Moorish art, which, from its historical associations, the great antiquity of the original, and the peculiar character, sentiments, and circumstances of the people by whom the structure was reared and beautified, cannot fail to be deeply interesting to every intelligent and philosophical visitor.

It is true that only a portion of the edifice, or group of edifices, has been (so to speak) reconstructed in the Crystal Palace; and that reconstruction or representation is necessarily very imperfect. Still, the parts which have been copied are the most important, and constitute the principal feature of the original; they have been constructed with great skill and fidelity, so that the visitor to the Crystal Palace may, from the objects there represented, form to himself a better idea of what the Alhambra was in the days of its glory, than if he were to travel to Grenada, and visit the ruined structure itself as it now stands.

Mr. Owen Jones has published a little manual illustrative of the Alhambra Court in the Crystal Palace, which every visitor to Sydenham may procure for a trifle, and which, with its numerous woodcuts, conveys a very good idea of the principles which regulate the ornaments of the structure. It may, however, be still more interesting to the reader, to give a general account of the palace itself, compiled from the works of an Arabian historian, who wrote when the original structure was comparatively complete and perfect. This account we shall begin with a description of the country, which unfortunately cannot be represented, or rivalled even by the pleasant gardens around the Crystal Palace.

The country surrounding Grenada is most delightful, and for the beauty of its environs, the salubrity of its climate, and richness of the country, the Arabs called it the Damascus of Spain. Few places, indeed, offer a more striking assemblage of objects deserving the attention of the antiquary, the naturalist, and the artist,—vestiges of Punic, Roman, and Arabian works,—mountains pregnant with minerals and marbles,—grand romantic scenes which may invite the pencil of a Poussin or Claude. The fruitful vale, or paradise as it has been called, fronting the city, is one of the finest in nature, and is computed at 100 miles in circuit. The plain is watered by numerous brooks and rivers, and in every direction there appear villages and gardens, which are adorned by beautiful buildings, trees and plants, while the circumjacent hills and mountains, for the space of forty miles, encompass the plain nearly in the form of a semicircle. At the extremity of this plain stands the renowned city of Grenada, which, with its elevated suburbs resting on five hills, rises partly on delightful acclivities, and partly extends itself into the plain, covered with buildings occupied by a numerous population. Language, indeed, can with difficulty describe, how happy, how charming it is rendered, by the softness of the air, the mildness of the climate, the bridges over the river, the splendour of the temples, and the convenience of its market-places. The city is divided by the river Darro, which flows from the east, and forming a junction with the Singalis, waters the whole plain, and which, like the Nile, after being augmented by numerous tributary rivulets and brooks, swells into a broad stream, and flows on to Seville.

In Grenada there was a garden attached to every house, and planted with orange, lemon, citron, laurel, myrtle, and other odoriferous trees and plants, whose fragrance purified the air, and promoted the health of its inhabitants. All the houses were supplied with running water, and in every street, through the munificence of successive sovereigns, there were copious fountains for the public convenience, and for the performance of religious ablutions; whatever, in short, could tend to promote the convenience and comfort of life, was here to be found in the richest profusion. The houses in the highest quarter of the city, which in the time of the Moors were particularly elegant, being beautifully ornamented with Damasquina work: the surplus of the abundant crops of corn was deposited in immense granaries excavated in the sides of the mountains. Grenada had twenty gates.

Enjoying a still more delightful prospect, continues the Arabian topographer, on the opposite side there rises, as it were, another city—the Alhambra, containing the royal residence. Here are seen lofty towers, very strongly fortified citadels, superb palaces, and other splendid edifices, the view of which fills the spectator's mind with admiration: here a vast mass of water, whose loud murmuring noise is heard at a distance, flows from various springs, and irrigates both the fields and meadows: the outer walls of the city of Grenada are surrounded by most choice and spacious gardens, where the trees are so thickly set as to resemble hedges, yet not so as to obstruct the beautiful *towers of the Alhambra, which sparkle among the leaves like stars.* No spot, in short, is without its orchards, vineyards, and gardens; and so abundant is the produce of fruit and vegetables reared on the widely-extended plain, that the wealth alone of the first princes can equal their annual value.

The Alhambra has been compared to Windsor Castle, situated upon the northern brow of a steep hill, commanding an extensive prospect over a beautiful country: the sides towards the citadel are so dilapidated, or encumbered with modern buildings, that very few traces are visible of the ancient external walls. The interior of the palace is still in good preservation, and attests the romantic splendour of its ancient kings. Even in its present deserted state, we recognise, in its architecture, the rank of the owner, the seat of power, and the gravity of the Arabian character.

The distribution of this interesting edifice is simple and natural; the courts, which in modern mansions are dull and unmeaning, are here so contrived as to seem a series of apartments, and the whole upon one plan throughout. Halls and galleries, porticoes and columns, arches, mosaics, viewed through the spray of falling waters, must have formed a view altogether enchanting; and although the Arabian architects were altogether unacquainted with perspective, the architectural arrangement and address is admirably adapted to make a building appear larger in its dimensions than it really is. Instead of the costly works of classic art, the Arabian khalifs adorned their courts and their harem with the simple productions of nature, and blessed the God of Mahomet for having given them that purity of taste to enjoy the exquisite pictures presented by nature in all their freshness and beauty, instead of adorning their dwellings with the cold and inanimate copies even from the hands of masters. Water in abundance was distributed in every part of the palace, and they were skilled in its management; they raised it in jets, which dispersed the floating miasmata; or they made it flow from fountains, and tempered the dryness and aridity of the atmosphere. At other times it was spread out in the middle of a court in a large sheet, reflecting buildings, fountains, flowers, and the "glorious sky of Grenada." The verge was bordered by white marble flags, with long narrow beds of roses ranged on either side,—a constant stream was made to flow in at one side and out at the other, keeping the surface of the water on the same horizontal plane with the floors, "and as smooth and even as the glass floor of the hall of audience, in which Solomon received the queen of Sheba."

CONCHOLOGY.

CHAPTER XI.

SUBDIVISION III.—SOLENAIRES.—(*Concluded.*)

Genus.—SANGUINOLARIA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, transverse, subelliptical, or ovate; compressed, sometimes transversely oblong, and for the most part thin, and generally covered with a glossy, olivaceous epidermis; length of the two sides of each valve varying in different species, and gaping at both extremities; margins generally rounded, but not parallel to each other; both valves provided with two cardinal teeth, but destitute of lateral teeth; ligament external, the fulcrum or space to which it is attached generally prominent; two very irregularly-shaped lateral muscular impressions in each valve, the pallial impressions with a large sinus.

Sanguinolaria Hollowaysii. Plate X. fig. 15.

The shells of this genus inhabit the seas of tropical climates. They are but few in number. Fossil *Sanguinolaria* are rare, and occur in the Oolitic group.

Genus.—EGERIA.—*Lea.*

Generic Character.—Shell generally subtriangular; two divergent cardinal teeth in each valve, one of which is cleft; with or without lateral teeth; internal margins crenated in some species; ligament external.

Egeria triangulata. Plate IX. fig. 3.

The species of this genus are all fossil, and have only been met with in the Tertiary formations of Alabama, America.

Genus.—GRATELOUPIA.—*Moulins.*

Generic Character.—Shell equivalve, inequilateral, subcuneiform, anteriorly rounded, posteriorly subrostrated; hinge with three cardinal teeth, a series of five or six irregular small divergent teeth behind the umbones, and one lateral anterior tooth in each valve; ligament external; muscular impressions two; pallial impression situate posteriorly.

Grateloupia Moulinsii. Plate IX. fig. 14.

Known only in a fossil state.

TRIBE II.—LITHOPHAGI.

Boring shells, destitute of accessary pieces, and more or less gaping at their anterior side; ligament of the valves external.

Genus.—PETRICOLA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, transverse, for the most part rather triangular, but some species are transversely elongated, and others subquadrate; posterior side rounded; anterior side somewhat produced, more or less attenuated, and generally gaping; each valve provided with two cardinal teeth, which in some instances are curved and acute, especially the posterior tooth in the left valve, and the anterior tooth in the right; the teeth are sometimes grooved internally, and the anterior tooth in one valve is broad and bifid; and in some instances the teeth are obtuse and short; two muscular impressions in each valve, that on the posterior side somewhat oblong, and the anterior one suborbicular; pallial impression with a large sinus; ligament external, but in some species nearly concealed by the prominent anterior margin of the valves near the beaks.

Petricola laminosa. Plate X. fig. 6. Distinguished from the Saxicava by having hinge teeth, and in being more regular in form.

The Petricolæ inhabit the ocean, and burrow in cavities of rocks or wood. They are found in a fossil state, and the species figured is met with in the Suffolk Crag.

Genus.—SPHENIA.—*Turton.*

Generic Character.—Shell transverse, equivalve, inequilateral, general form flattish, wedge-shaped, gaping at the anterior end; hinge of the left valve with an elevated transversely dilated tooth; that of the right valve with a concave tooth, and a small denticle behind it; destitute of lateral teeth; two small muscular impressions in each valve; pallial impression with a large tongue-shaped sinus, emanating from the anterior side, and reaching nearly to the middle of the valves; ligament external.

Sphenia Binghami. Brown's Foss. Conch., Plate XC. figs. 44, 45.

Found in the Coral Crag, Sutton, &c.

Genus.—SAXICAVA.—*Fleuriau de Bellevue.*

Generic Character.—Shell transverse, irregular in form, generally oblong, inequilateral, subequivalve, gaping anteriorly; ligament exterior; two lateral muscular impressions in each valve; pallial impression interrupted but not sinuated; hinge in the young condition, with sometimes two or three minute, obtuse, mostly indistinct cardinal teeth, which become obsolete in the adult.

Saxicava rugosa. Plate X. fig. 5.

The Saxicavæ are marine shells, and seem principally confined to temperate climates; they burrow in wood, clay, or limestone, and other soft rocks. Fossil species are met with in the Suffolk Crag and newer formations.

Genus.—AGINA.—*Turton.*

Generic Character.—Shell transverse, oval, equivalve, inequilateral, open at the anterior side; hinge with a single erect, conic, penetrating cardinal tooth in each valve; destitute of lateral teeth; ligament external.

Agina purpura. Brown's Foss. Conch., Plate XC. figs. 26, 27. The Coral Crag, Sutton.

TRIBE III.—CORBULACEA.

Shells inequivalve; the ligament interior.

Genus.—PANDORA.—*Lamarck.*

Generic Character.—Shell free, thin, internally pearlaceous, inequivalve, transverse, inequilateral, the anterior side the longer, subrostrated and slightly gaping at its extremity; one valve flat, with two internal anterior ribs, and with its anterior margin turned downwards, provided with a single oblong, obtuse cardinal or hinge-tooth, situate behind the ligament; the opposite valve concave, and destitute of teeth, but furnished with an indistinct cicatrice on which the tooth of the flat valve rests when the shell is closed; in each valve are two distant lateral muscular impressions; ligament internal, its sides lodged in and attached to an elongated cicatrice, which lies inclined to the anterior side of the valves; in some species the cicatrice is produced into an elongated divergent lamina, stretching from the umbo towards the anterior side of the shell, and terminating near the inner side of the anterior muscular impression.

Pandora Defrancii. Plate X. figs. 24 and 27.

This genus is distinguished from *Tellina* by its internal ligament, and from *Corbula* by its single obtuse tooth in one valve only.

The Pandoræ are marine shells, and have been found in a fossil condition in the Calcaire-grossier.

Genus.—CORBULA.—*Bruguière.*

Generic Character.—Shell inequivalve, one valve being generally small and flattened, the other large and convex; subequilateral, transverse, generally gibbose and close; each valve usually furnished with a single conical, recurved, ascending, pointed tooth, at the side of which is a small concave depression,—very deep in some species, which serves either for the reception of the ligament, or the tooth of the opposite valve; two distant, lateral, somewhat irregular muscular impressions in each valve; pallial impression posteriorly angulated, with a very small sinus; ligament internal, fixed to the tooth of the lesser valve, and inserted in the depression by the side of the tooth in the larger valve.

Corbula revoluta. Plate X. fig. 18.

The Corbulæ inhabit the ocean, and are pretty numerous. They are frequently found in a fossil state in the English Crag, Greensand, and London Clay, and contemporaneous formations.

The shells of this genus differ from those of Mya, in having a sinus in the pallial impression, and in their prominent ligamentiferous tooth in each valve, while the Myæ have only one.

Genus.—NÆARA.—*Gray.*

Generic Character.—Shell transversely ovate, very convex, posterior side large and rounded; anterior side abruptly tapering to a lengthened and acuminated beak-like elongation; beaks small, inflated; hinge with one large, elevated, and recurved cardinal tooth in the right valve, which fits into a pit, under the edge of the superior margin of the left valve; cartilage attached in central pits beneath the beaks; two muscular impressions in each valve; pallial impression obsolete.

Nœara dispar. Brown's Foss. Conch. Plate XCIII. fig. 21. In the London Clay, Barton.

Genus.—POTOMOMYA.—*J. Sowerby.*

Generic Character.—Shell subtriangular, inequivalve, gaping, and generally subtruncated at the anterior side; left valve encompassing the other all round, receiving its edges upon the thickened parts on each side of the hinge; right valve with a large, erect, spoon-shaped double tooth; left valve with a small hollow for the reception of the ligament; pallial impression with a small rounded sinus, forming a quarter of a circle, situate close to the anterior muscular impression.

The remote tooth, with its accompanying hollow, forming a secure rest from the edges of the opposite valves; the inequality of the valves, and the form and situation of the sinus, are the chief characters which distinguish this genus from that of Mya.

Potomomya gregaria. Brown's Foss. Conch. Plate XC. figs. 8 and 10.

Fresh-water formation, top of Headon Hill, Isle of Wight.

TRIBE IV.—MATRACEA

Shells equivalve, often gaping at the lateral extremities; ligament internal, or partly external; animal with the foot small and compressed.

SUBDIVISION I.—Ligament seen externally or double.

Genus.—AMPHIDESMA.—*Lamarck.*

Generic Character.—Shell equivalve, transverse, slightly inequilateral, somewhat ovate or orbicular; some species gaping at the sides; each valve provided with one, or in some instances two small, slender, cardinal teeth; and two distinct elongated lateral teeth, situate near the hinge in one valve, and are nearly obsolete in the other; pallial impression with a very large sinus; ligament double, its external portion slender and rather short, and the internal cartilage generally longer and larger, adherent in both valves to an elongated groove or pit, which varies in length in different species, and takes its rise immediately within the umbo, and is prolonged within the anterior lateral tooth.

Amphidesma decaratum. Plate IX. fig. 1.

The larger species of this genus are provided with a flexure in the anterior margin of both valves, as in the Tellinæ.

The inner portion of the ligament being at a distance from the cartilage, distinguishes the shells of this genus from all others, because in most univalves the cartilage and ligament are united in one mass, or situated close to each other. Although the Lutrariæ have a tendency to this structure, they differ from that genus in their lateral teeth, and by the valves being almost entirely close, while in the Lutrariæ they gape widely at one end.

The Amphidesmæ are oceanic shells, inhabiting the seas of all countries. Fossil species (if they really are true Amphidesmæ) are exceedingly rare, and occur in the Cornbrash, Kelloways rock, and upper Lias shale; the *A. decaratum* belongs to the Cornbrash.

SUBDIVISION II.—Shell not gaping at the sides; ligament external.

Genus.—ERYCINA.—*Lamarck.*

Generic Character.—Shell smooth, transverse, ovate, or triangular, equivalve, generally inequilateral; and one valve with two unequal, thick, divaricate, cardinal teeth, with an intermediate pit for the reception of the ligament, and two oblong, compressed, short lateral teeth, situate near the primary teeth; the opposite valve is destitute of cardinal teeth, or they are quite obsolete; in some instances one of them is united to the anterior lateral tooth, which is always very short, and thus increases its thickness; the lateral tooth in this valve is compressed and oblong; two lateral pallial muscular impressions, with a small sinus, ligament internal, affixed in each valve into a narrow, concave space between the teeth.

Erycina fragilis. Plate X. fig. 14.

The Erycinæ are distinguished from the Crassatella, Lutraria, and Mactra, by the manner in which the teeth are situate on each side of the ligamentiferous pit, while in the two latter genera they are both situate on the anterior side; it is known from the former genus by the sinus in the mantle muscular impression, and its distant and compressed lateral teeth.

The shells of this genus are marine, and have been met with in a fossil state in the supercretaceous rocks of Bordeaux and Dax. The species are very rare in a fossil condition.

Genus.—CRASSATELLA.—*Lamarck.*

Generic Character.—Shell thick, equivalve, transverse, inequilateral; external surface generally covered with a brown horny epidermis, and more or less transversely grooved; one valve provided with two strong cuneiform, rugose cardinal teeth, which are sometimes perpendicularly grooved; and one primary tooth in the opposite valve; lateral teeth awanting or nearly obsolete, two strong oblong depressions, the one on the anterior side of the umbo somewhat elongated, and not so well marked as that in the posterior side; two remote, lateral, rather oblong muscular impressions; ligament internal, attached to a concave pit situate on the anterior side of the hinge; this space is divided by a rib into two portions, the outer half of the ligament is externally visible when the valves are closed.

Crassatella sulcata. Plate IX. fig. 4.

The Crassatellæ are marine shells, and principally inhabit the coasts of New Holland.

Fossil species are met with in the London Clay, and Calcaire-grossier, near Paris.

Genus.—THETIS.—*Sowerby.*

Generic Character.—Shell equivalve, subequilateral, more or less orbicular and convex; ligament marginal; hinge with three or four acuminated cardinal teeth, but destitute of lateral teeth; pallial impression with a deep sinus extending nearly to the beak; muscular impressions round, small, and remote from the hinge; ligament external.

Thetis minor. Plate IX. figs. 20 and 25.

The shells of this genus are all fossil, and occur principally in the lower Greensand of Sussex, Lyme-Regis, and Isle of Wight.

SUBDIVISION. III.—Ligament internal; shell gaping at the sides.

Genus.—MACTRA.—*Linnæus.*

Generic Character.—Shell generally thin, sometimes thick; equivalve, for the most part nearly equilateral, and more or less regularly triangular; slightly gaping at one end, and almost imperceptibly so at the other; each valve with one V-shaped cardinal tooth, the point being next the umbo, and diverging from it, and in some species the limbs are disunited at the base, so as to give the appearance of two distinct teeth; close on the posterior side is situate a very thin sharp tooth; immediately behind the angular tooth is situate the pit for the reception of the ligament, and projecting somewhat within the shell; one valve with two lateral teeth on each side, and one on both sides in the other, diverging from the beaks, placed near the margin of the shell, and fitting into the space between the two in the opposite valve; two lateral, remote muscular impressions; mantle muscular impression with a small sinus; ligament consisting of two portions, the one considerably larger than the other and internal, and the other half external.

Mactra semisulcata. Plate X. fig. 8.

In the thick species the lateral teeth are perpendicularly striated; these are generally elongated, with the inner ones more prominent than the outer; they are quite short in some

species, such as the M. Spengleri. The beaks are separated in some species, and the ligament placed in a groove or pit extending both internally and externally to the beak.

The Mactræ inhabit the seas of almost all climates. Fossil species are found in the Secondary and Tertiary formations, especially in the Oolite of the former.

Genus.—LUTRARIA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, thin, transversely ovate or oblong; gaping at both sides; the posterior side generally the longer, and always gaping more than the other; one valve with two thin laminar teeth, one of which is sometimes compound; the opposite valve with three teeth, the central one compound in some instances, and the posterior one slender and compressed; two distant lateral muscular impressions; muscular impression of the mantle with a large sinus; ligament internal, situate in a deltoidal, oblique, internally projecting spoon-shaped pit, with a prominent margin placed next to the teeth in each valve.

Lutraria sulcata. Plate IX. fig. 24. Found in the Mountain Limestone, Northumberland.

The Lutrariæ are distinguished from the Mactræ, by their wanting lateral teeth, and the large sinus in the mantle muscular impression. The internal ligament removes them from the Anatinæ.

The shells of this genus inhabit the sea; and it is quite uncertain if any true Lutrariæ have been found in a fossil state, although several species have been described as such.

GRAND DIVISION IV.—CRASSIPEDES.

Mantle entirely or partly united before, foot thick, placed posteriorly, shell gaping when closed.

TRIBE I.—MYARIA.

Ligament internal; a broad spoon-shaped tooth in each valve, or in one only; shell gaping at both sides, or at one only.

Genus.—MYA.—*Linnæus.*

Generic Character.—Shell transverse, nearly equivalve, gaping at both extremities, but widest at the posterior side; one valve with one large, compressed, dilated, hollow, spoon-shaped, perpendicular, vertically projecting tooth; the opposite valve destitute of teeth; the cartilage placed in a narrow suture; two lateral, distant, large muscular impressions, the anterior one narrow, and the posterior almost orbicular; pallial impression with a large sinus; ligament internal, large, and fixed in the cavity of the tooth in one valve, and to a large subumbonal cicatrix in the other.

Mya lata. Plate IX. fig. 34.

The Myæ are easily distinguished by the large upright tooth in one valve only; they are marine shells, and inhabit the seas of the Northern hemisphere.

They are found in a fossil state in the Crag, the Blue Marls of France, and also in the Cretaceous and Oolitic group of rocks.

Genus.—THRACIA.—*Leach.*

Generic Character.—Shell very thin, transverse, inequivalve, inequilateral, one valve usually more convex than the other; beaks generally obtuse and subcentral; hinge with a broad, transverse, frequently thickened tooth in the centre, in which the cartilage is situate; surface, in the recent state, covered with a very thin epidermis; two well-marked but dissimilar muscular impressions in both valves; pallial impressions interrupted by an arcuated sinus at the posterior side, which is truncated.

Thracia oblata. Brown's Foss. Conch. Plate XCIII. figs. 2, 3. The London Clay, Pegwell, Herne Bridge, and Bognor.

Genus.—ANATINA.—*Lamarck.*

Generic Character.—Shell transverse, inequilateral, generally with unequal valves; sometimes gaping at both ends, and in some species nearly closed; generally provided with a small accessory spoon-shaped appendage internally in each valve, to which the ligament is attached; connected with this, and also adhering to the ligament, is a small irregularly-shaped testaceous internal process, which serves to assist in strengthening the adhesion between the valves.

Anatina undulata. Brown's Foss. Conch. Plate XC. fig. 30. The Calcareous Grit, Malton, and Brora.

Genus.—LYSIANASSA.—*Münster.*

Generic Character.—Shell thin, transverse, inequilateral, oval, convex, or ventricose; gaping at both sides; surface ribbed; those ribs on the cardinal margin anteriorly bent backwards, and on the posterior side bent forwards, and radiating on the middle of the valves; beak subcentral; hinge unknown.

Lysianassa anguilifera. Brown's Foss. Conch. Plate XCII. fig. 32.

In the Fuller's Earth, Smallcomb, Bath, and Bathford Hill.

TRIBE II.—SOLENIDES.

Shell transversely elongated, destitute of accessory pieces, and gaping only at the lateral extremities; ligament external.

Genus.—PANOPÆA.—*Menard de la Grove.*

Generic Character.—Shell equivalve, oval, inequilateral, gaping unequally at both extremities; hinge with an acute primary tooth in each valve, and a large callosity near the umbones, supporting the ligament; two distant, oval, muscular impressions, pallial impression with a large sinus; ligament large, external, adhering to an ample prominent fulcrum.

Panopœa bivonæ. Plate IX. fig. 16.

The shells of this genus bear a general resemblance to those of Mya, but differ in having a sharp tooth and external ligament, instead of the broad spoon-like process in the hinge of Mya.

They inhabit the ocean, and one species has been dredged off Scarborough.

In a fossil state they are met with in the Blue Marls of France, the supercretaceous rocks of Bordeaux and Dax, and in the Greensand.

Genus.—SOLEMYA.—*Lamarck.*

Generic Character.—Shell equivalve, inequilateral, transversely oblong, rounded at the extremities; beaks near the posterior side; hinge destitute of teeth; ligament partly external, situate in the margin of an oblique, flattish, posterior rib; two distant, lateral muscular impressions.

Solemya primæva. Brown's Foss. Conch. Plate XCIII. fig. 10.

In the Carboniferous Limestone, Heiton; Lowick and Fermanagh, Ireland.

Genus.—SOLEN.—*Linnæus.*

Generic Character.—Shell equivalve, transversely elongated, subcylindrical, prodigiously inequilateral, umbones nearly terminal, situate close to the anterior side, and gaping widely at both extremities; truncated, or subtruncated, sometimes rounded; hinge linear, with several small cardinal teeth, various in form, often acute and recurved; lateral teeth somewhat elongated and crooked; muscular impressions distant, tongue-shaped, the anterior one joined a little behind the umbones; the posterior one irregular and suboval; pallial impression elongated, straight, and bifurcated behind; ligament long and exterior; external surface covered with a thick horny epidermis.

Solen fragilis. Plate X. figs. 16, 17.

The above generic character embraces only those shells whose general form corresponds with *Solen siliqua.* The others are separated under different generic appellations.

The Solens inhabit the ocean, concealing themselves in sand.

But few fossil species have been found, and these occur in the London Clay, and Calcaire-grossier of France.

Genus.—PHOLADOMYA.—*Sowerby.*

Generic Character.—Shell transverse, inequilateral, equivalve, ventricose, very thin and hyaline, anterior side more or less elongated and gaping; posterior side sometimes very short, rounded; upper edge slightly gaping; hinge with a small, rather elongated triangular pit, and a marginal lamina in each valve; to the outer surface of which is attached a somewhat short

external ligament; inside pearlaceous; two indistinct muscular impressions, muscular impression of the mantle nearly obsolete, and with a large sinus.

Pholadomya angustata. Plate IX. fig. 29. *P. lirata.* Plate X. fig. 9.

The *P. candida* is the only recent species of the genus known; it is found on the coast of the Island of Tortola. The umbones are so close to each other, that they are worn through by the attrition of opening and shutting of the valves.

The shells of this genus partake of the characters of Anatina and Pholas, but may be distinguished from them by the external ligament, and the want of accessory valves; in the structure of the hinge they are allied to Panopæa, but differ in their extreme thinness, transparency, and pearly texture, and from Mya, in wanting the unequal teeth of that genus.

Fossil species are pretty numerous, and occur in the Inferior Oolite, Cornbrash, Fuller's Earth, the London Clay, Lias, and the Sutherland coal-field.

TRIBE III.—PHOLADARIA.

Shell bivalve, with accessory pieces to the valves; gaping much anteriorly.

Genus.—PHOLAS.—*Linnæus.*

Generic Character.—Shell transversely oblong, equivalve, greatly inequilateral; nearly the whole species gaping at both sides, and most of them with the opening very large at the anterior side, and extending along the basal margin; in some species, however, it is nearly closed by a testaceous, almost smooth, somewhat tubular prolongation of the valves; hinge in various species with an unequally-sized small recurved tooth in each valve; external surface generally roughened with muricated striæ, presenting a rasp or file-like appearance; most of the species provided with a greater or lesser number of accessory valves, situate near the fulcrum of the hinge, and connected with the shell only by the epidermis, which passes over them; each valve furnished with a long curved, flat, tooth-like testaceous process, projecting from the interior of the shell, immediately within the umbones; in some species this is expanded and spoon-shaped; anterior dorsal margin near the beaks reflected close, and flattened down upon the umbones in some species, and in others a second margin is produced, situate remote from the first, with the intervening space divided by a series of transverse septa; two principal impressions, formed by the adductor muscle, one of which is placed on the reflected margin over the beaks, and the other intermediate, between the umbones and the posterior side; muscular impression with a large sinus in its narrower part, the impression being somewhat expanded near to the sinus.

Pholas aperta. Plate X. figs. 21, 26, and 28.

The Pholades differ from the Teredines, chiefly in the latter having a testaceous tube situate *behind* its valves, in having no accessory appendages or valves, and when the valves are closed, they assume nearly a globular form. Turton's genus *Xylophaga* is provided with accessory valves, but is destitute of the testaceous tube, and the internal shelly tooth-like process of *Teredo* and *Pholas.*

The Pholades inhabit the ocean, and are found in the seas of all countries, burrowing in limestone rocks, wood, or clay. They are rare in a fossil state, and those known have been found in the English Crag, in the Calcaire-grossier of France, and its contemporaneous formations in Touraine and Italy. Some of these have been found in the cavities which they themselves have made.

TRIBE IV.—TUBICOLA.

Animal contained in a testaceous sheath, distinct from its valves, incrusted entirely or in part in the wall of this tube, or projecting outwards.

Genus.—GASTROCHÆNA.—*Spengler.*

Generic Character.—Shell equivalve, inequilateral, somewhat wedge-shaped; anterior side rounded when viewed in front, and posteriorly acuminated; anterior side gaping widely, its aperture being subovate, and acute behind; hinge marginal and linear, destitute of teeth, but in their stead a small laminated appendage, emanating from the umbo, allied to the same tooth-like process in the genus *Pholas;* ligament external.

Gastrochæna contorta. Plate X. fig. 19.

This shell is enclosed in a testaceous, irregular, claviform tube, situate at its broader extremity; it is open and attenuated anteriorly, with an oblong, bilobate aperture, which is nearly subdivided by a projecting septum, that does not quite reach across the opening; these serve for the passage of the two tubes of the animal; the posterior end of the tube is closed. This club-shaped tube is found either within the perforated cavities of rocks, or in old shells or corals, the testaceous tube always protruding beyond the surface.

The Gastrochæna are readily distinguished from the Pholades by their testaceous tube, and by wanting accessory valves; they seem the connecting link between the *Pholadaria* and *Tubicola.* They differ from the *Fistulanæ* in the oval form of the valves, and in the curvature of the tube, from *Clavagella* and *Aspergellum* in both valves being free, and from *Galcoma* in the shell being free and oblique.

The shells of this genus inhabit the ocean, and only one fossil species has been found, attached to the inside of other fossil shells in the Calcaire-grossier at Grignon, France.

Genus.—TEREDINA.—*Lamarck.*

Generic Character.—Shell orbicular, and entirely external, equivalve, inequilateral; umbones greatly incurved, and covered by a somewhat quadrangular, accessory process, which seems to be fixed to the valves in front of the beak, with a subulate process in front, and gaping at both extremities; anterior opening angular at the back, and the posterior rounded in front; tube thick, fistulous, posterior extremity smaller and open, and nearly divided into two from an interior projection on both sides, and provided with an operculum; anterior termination of the tube entirely closed by a trapezoidal plate, which fills up the space left by the sinus in the two valves.

The posterior portion of the tube is of a different consistence from the anterior part, having a horny texture and appearance; the interior of the valves is thickly lined with the same testaceous matter as the tubes. This testaceous substance is generally so much thickened in front, that it almost entirely conceals the tooth-like process.

Teredina personata. Plate X. figs. 22, 23.

The shells of this genus are known only in a fossil state, and seem to have been gregarious. They are found plentifully in the Ferruginous sand.

Genus.—FISTULANA.—*Bruguière.*

Generic Character.—Shell equivalve, inequilateral, transversely elongated, and gaping widely at the basal margin; anterior side very short; valves attached by a ligament, and situate in the lower part of a testaceous tube, which is closed at the lower or anterior extremity, and to which they are confined by the septum, and open at the centre; the posterior end attenuated and open.

Fistulana pyriformis. Plate X. figs. 29, 30.

We exclude all the Lamarckian species of Fistulanæ except *Fistulana Clava*, which is the type. *F. Lagenula, Appularia,* and *Pyrum* are *Gastrochæna. F. cornifornus* is a *Teredo,* and *F. gregata* is a *Teredina.*

Distinguished from the Gastrochæna by the oblong shape of the valves and straightness of the tube.

The Fistulanæ are marine shells, and are few in number. Fossil species are also few, and occur in the Calcaire-grossier.

Genus.—CLAVAGELLA.—*Lamarck.*

Generic Character.—Shell consisting of a testaceous tube, somewhat attenuated, and open at its anterior extremity, irregularly ovate, subcompressed, claviform, and closed at its lower end, excepting by a number of irregularly-formed minute tubes; clavate termination provided with an irregular, thin, flattened, pearly adherent valve on one side, with a loose extremely thin valve at the bottom of the tube, which is supposed to be united to the fixed valve by a ligament in a living state; an irregular muscular impression near one side.

The tube of the Clavagellæ is sometimes free, and at others it lines submarine bodies, such as madrepores, stones, and clay.

Clavagella Coronata. Plate X. fig. 31.

The shells of this genus inhabit the ocean; and they have been met with in a fossil condition in the London Clay, and in the supercretaceous rocks of Bordeaux.

CLASS—CIRRIPEDES OR BARNACLES.

The animals are soft, destitute of a head, and consequently eyes, covered with a shell, and are incapable of locomotion, being always affixed to extraneous bodies. The whole of the Cirripedes are testaceous multivalves, that is, consisting of more than two pieces, or valves.

ORDER I.—PEDUNCULATA.

Body supported on a tubular, membranaceous, moveable peduncle, the base of which is affixed to stones and other marine bodies, or timber floating in the ocean.

Genus.—POLICIPES.—*Leach.*

Generic Character.—Body covered by a testaceous shell, and supported by a tubular, tendinous, squamiferous peduncle, which seldom exceeds two inches in length; shell multivalve, compressed on the sides, with the valves nearly contiguous and unequal; valves thirteen or more in number, those on the side smallest; five upper valves much larger than the others, the anterior pair conical, elongated, with their sides reflected backwards, situate on each side of the opening; the central or terminal pair largest, and trapeziform, with an acute angle at the posterior extremity; dorsal valve greatly elongated, broad at the base, rounded in the back, with an acute apex; between these, in the peduncle, are a number of smaller, testaceous, generally triangular studs.

Policipes sulcatus. Plate X. fig. 32; figs. 42 and 43, two of its valves. *P. reflexus*, two of its valves, figs. 39, 40.

The Policipes are marine shells; a very few species are known in a fossil condition; these have been met with in the Suffolk and in the Norfolk Chalk, and also in the Gault and Greensand of England.

ORDER II.—SESSILIA.

Destitute of a peduncle; body enclosed in a multivalve shell, attached by its base to marine bodies; mouth situated at the upper and interior portion of the body.

Genus.—BALANUS.—*Lamarck.*

Generic Character.—Shell sessile, conical, or subconic, closed at the base by a testaceous plate, which adheres to extraneous substances, consisting of four articulated valves; aperture subtrigonal or elliptical, and shut by an operculum composed of four valves.

Balanus tessilatus. Plate X. fig. 38.

The Balani are exceedingly variable in form, depending upon the shape of the substance to which they are affixed. Fossil species occur in the newer formations, the one we have figured was found at Bramerton, Norfolk. They also occur in the marine sands of the Blue Marls of France and Italy.

Genus.—ADNA.—*Leach.*

Generic Character.—Shell consisting of an upper valve, supported on a funnel-shaped base, which is not sunk in the substance to which it is attached, but is seen externally; the operculum consisting of four valves.

Adna sulcata. Brown's Foss. Conch. Plate XCVII. fig. 59.

In the Coral Crag, Ramshot.

Genus.—CORONULA.—*Lamarck.*

Generic Character.—Shell seated, suborbicular, valves apparent, indivisible, conoidal, with very thick walls, and interiorly hollowed in radiating cells, eighteen in number; aperture regular, of a rounded oval form, and interiorly funnel-shaped; operculum, with four obtuse valves.

Coronula Diadema. Brown's Foss. Conch. Plate XCVII. figs. 47, 48.

In the Red Crag, Sutton.

Genus.—CLITIA.—*Leach.*

Generic Character.—Shell a depressed irregular-shaped cone, attached by the base, and consisting of four unequal, dissimilar valves, two larger and two smaller, laterally united by the interlocking of their dentated margins; aperture somewhat trapeziform, laterally placed, and entirely filled by a bipartite operculum, one of the pieces of which is irregularly quadrate, and the other nearly triangular.

Clitia verruca. Brown's Foss. Conch. Plate XCVII. fig. 61, 61.*

CLASS ANNELIDES.

Animal with a more or less elongated body, having no blood, and inhabiting a testaceous tube, from which they never depart.

ORDER I.—SEDENTARIA.

Tube elongated and testaceous.

TRIBE I.—SERPULACEA.

Tube solid and calcareous.

Genus. —SERPULA.—*Linnæus.*

Generic Character.—Shell tubular, narrow, gradually widening towards the aperture, and pointed towards the apex; attached irregularly to other bodies; sometimes wound spirally; keeled, imbricated, or plain; aperture round for the most part, or angulated in the ribbed species.

Serpula tricarinata. Plate X. fig. 36. *S. diplixa*, fig. 35.

We have united the genera Serpula and Vermilia, there not being sufficient distinctive generic characters for both. They are extremely variable in form, and are met with in all seas. We have given an example of the expunged genus Vermilia, viz. *V. sulcata.* Plate X. fig. 34.

Fossil Serpulæ are extremely abundant, and occur in almost all formations, from the newest to the Grawacke group. They are among the few shells which have existed through all ages to the present time.

Genus.—FILOGRANA.—*Berkeley.*

Generic Character.—Shell very slender, filiform, gregarious, provided with eight filiform branchiæ, of which two bear an infundibuliform, obliquely truncated operculum; mantle rectangular; each side furnished with seven fascicles of bristles.

Filograna Permiana. Found in the Permian series, Black Hall Rocks, Coast of Durham.

Genus.—VERMILIA.—*Lamarck.*

Generic Character.—Tube cylindrical, posteriorly narrowed, more or less twisted, and adhering by the side to extraneous bodies; aperture rounded, and the margin frequently provided with from one to three denticles.

Vermilia ampullacea. Brown's Foss. Conch. Plate XCVIII. figs. 31, 45.

In the Chalk, Norwich and Lewis, and the Greensand, Blackdown.

Genus.—SPIRORBIS.—*Lamarck.*

Generic Character.—Shell consisting of a testaceous tube, spirally twisted into an orbicular form or a horizontal plane, depressed, and adhering below; the aperture terminal, rounded, or angular.

Spirorbis tenuis. Plate XI. fig. 13.

Found in the Silurian series of rocks.

Genus.—CYCLOGYRA.—*S. Wood.*

Generic Character.—Shell discoidal, thick; surface with rows of very prominent grains; aperture nearly circular, its lip fringed with protuberant grains.

Cyclogyra granulata. Brown's Foss. Conch. Plate XCVIII. fig. 27.

TRIBE II.—MALDANIÆ.

Branchiæ of the animal intermediate, tube open at both ends.

Genus.—CORNUOIDES.—*Brown.*

Generic Character.—Shell tubular, cylindrical, erect, abruptly tapering, and slightly convoluted at the smaller end, which is imperforate; aperture circular.

Cornuoides major. Brown's Foss. Conch. Plate XCVIII. fig. 50.

The Coral Crag, Sutton.

Genus.—SERPULITES.—*Murchison.*

Generic Character.—Tube much lengthened, hardly diminishing in diameter, compressed, smooth, and a little tortuous, composed of thin laminæ of shell combined with much animal matter.

Serpulites longissimus. Brown's Foss. Conch. Plate XCVIII. fig. 39.

In the Upper Ludlow Rock, Ludlow and Kington.

Genus.—DENTALIUM.—*Linnæus.*

Generic Character.—Shell tubular, open at both ends, arcuated, increasing in the diameter towards the wider extremity, where the aperture is large and round; opening of the pointed end very small, and with a lateral fissure in some species; external surface ribbed, striated, or smooth.

Dentalium nitens. Plate X. fig. 41.

The shells of this genus have the miniature form of an elephant's tusk. They inhabit all seas, and are pretty numerous in species. They occur in a fossil state in the Blue Marls of France, the London Clay at Highgate Hill, and Avignon, France; Folkestone, and Barton Cliffs, and a few are met with in the Limestones of Bognor and Exmouth.

THEORY AND PRACTICE OF NAVIGATION.

CHAPTER VI.

V.—ON FINDING THE LONGITUDE BY CHRONOMETERS.

Example 1.

April 20, 1855.—A chronometer was found to be *fast*, for mean time at Greenwich, 1m. 12s., and gaining 6s. 7 per day.

May 16, 1855, *p.m.*—The following altitudes of the sun's lower limb were observed, with the corresponding times, by the above chronometer, the height of the observer's eye being 20 feet, and the instrument properly adjusted; the latitude at apparent noon being 40° 30′ N., since which the ship has run N.W. ¾W. 30 miles, the sun bearing S. 58° 26′ W. What is the true longitude of the ship, and the variation of the compass?

Times by Chronometer.

	H.	M.	S.
	5	50	30
	5	59	28
	6	4	56
Sum of times, - - - - -	3)17	54	54
Mean of the times, - - - -	5	58	18
Original error, - - - - - -	—	1	12
	5	57	6
Accumulated rate, - - - -	—	1	49
Mean time at Greenwich, - -	5	55	17

Observed Altitude of Sun's Lower Limb.

	43°	6′	9″
	42	56	19
	42	43	34
Sum of altitudes, - - - -	3)128	46	2
Mean of altitudes, - - - - -	42	55	21
Corresponding table + 10′·6, - -	+	10	36
Sun's true altitude, - - - - -	43°	5′	57″

	S.
Daily gain, - - - - - - - -	6·7
Days from April 20th to May 16th, - - -	16
	40·2
	67·
	60)107·2
Gain in 16 days, - - - - -	1m. 47s. ·2
Gain in 6 hours, - - - - -	+ 1s. ·6
Accumulated rate, - - - - -	1m. 48s. ·8

Equation of time, - - - - -	3	53·36		May 16.
Hourly difference, 0s. ·5 × 6h. = -		0·30		
Equation of Greenwich time, - -	3	54 ·6		May 16.
Sun's declination, - - - - -	19°	2′	12″ N.	May 16.
Hourly difference + 28″ ·8 × 6 = +		2	48	
Sun's declination at Greenwich time =	19	5	0 N.	
	90			
Sun's polar distance, - - =	70°	55′		

Latitude of ship at noon, - - - - -	40°	30′ N.
Difference of latitude (N.W. ¾W. 30m.),	+	18 N.
Latitude when sights were taken, - - -	40°	48′ N.

Sun's true altitude, - - - - -	43°	6′
Polar distance, - - - - - -	70	55
Ship's latitude, - - - - - -	40	48
Sum, - - - - - - - -	154°	49′
Half sum, - - - - - - -	77	24
Remainder for time, - - - - -	34	18
" azimuth, - - - - -	6	30

Polar distance, secant, - - - -	0·02455
Ship's latitude, secant, - - - -	0·12091
Half sum, cosine, - - - - -	9·33874
Remainder for time, sine, - - -	9·75091
Logarithm, - - - - - -	9·23511
Sun's true altitude, secant, - - -	0·13658
Ship's latitude, secant, - - - -	0·12091
Half sum, sine, - - - - - -	9·33874
Remainder for azimuth, cosine, - -	9·99720
	2)19·59343
Sine, - - - - - 38° 46′ =	9·79671
2	

True azimuth, - -	S. 77	32 W.
Magnetic azimuth, -	S. 58	26 W.
Variation, - - - -	19°	6′ E.

	H.	M.	S.	
Apparent time at ship, - - -	3	15	55	
Equation of time, - - - -	—	3	53	
Mean time at ship, - - - -	3	12	2	May 16.
Mean time at Greenwich, - - -	5	55	17	"
Longitude in time, - - - - -	2	43	15 =	
	40°	48′	45″ W.	

Example 2.

May 4, 1855.—Suppose a chronometer to be *slow*, for mean time at Greenwich, by 2m. 36s., and *gaining* 4s. 4 per day.

May 28, 1855, *a.m., civil time.*—The following altitudes of the sun's lower limb were observed, with the corresponding times, by the same chronometer, when the sun was bearing N.:—E., the height of the observer's eye being 26 feet, and the error of the sectant, 1′ 8″, to add; the latitude at apparent noon, 12° 50′ S., and the ship's true course, E. by S. ½S. 28 miles since the sights were taken. What is the true longitude of the ship, and the variation of the compass?

Times by Chronometer.

	H.	M.	S.
	19	40	50
	19	48	54
	19	55	40
Sum of times, - - - - -	3)59	25	24
Mean of times, - - - - -	19	48	28
Original error, - - - - -	+	2	36
	19	51	4
Accumulated rate - - - - -	—	1	44
Mean time at Greenwich, May 27, - -	19	49	20

Observed Altitude of Sun's Lower Limb.

	12°	30′	40″
	12	48	50
	12	56	48
Sum of altitudes, - - - - -	3)38	16	18
Mean of altitudes, - - - - -	12	45	26
Index error, - - - -	+	1	8
	12	46	34
	+	7	0
Sun's true altitude, - - - -	12°	53′	34″

	S.
Daily gain, - - - - - - -	4·4
Days from May 4th till May 27th, - - -	2·3
	132
	88
	60)101·2
Gain in 23 days, - - - - - -	1m. 41s. ·2
Gain in 20 hours - - - - - -	3s. ·6
Accumulated rate, - - - - - -	1m. 44s. ·8

	M.	S.	
Equation of time, - - - - -	3	12·24	May 27.
Hourly difference + 0s. 26 × 20h. =	+	5·20	
Equation at Greenwich time, - -	3	17·44	

Sun's declination, - - - -	21°	15′	18″ N.	May 27.
Hourly difference — 25″ × 20h. =		8	3	
Sun's declination at Greenwich time,	21	7	15 N.	
	90			
Sun's polar distance, - -	111°	7′	15″	

Latitude of ship at noon, - - - - -	12°	50′ S.
Difference of latitude E. by S. ½S., 28 miles,	+	8 S.
Latitude when sights were taken, -	12°	58′ S.

Sun's true altitude, - - - - -	12°	53′
Polar distance, - - - - - -	111	7
Ship's latitude, - - - - - -	12	58
Sum, - - - - - - - -	136	58
Half sum, - - - - - - -	68	29
Remainder for time, - - - - -	55	36
" azimuth, - - - -	42°	38′

Polar distance, cosecant, - - - - -	0·03019
Ship's latitude, secant, - - - - -	0·01122
Half sum, - - - - - - -	9·56440
Remainder for time, sine, - - -	9·91651
Logarithm, - - - - - - -	9·52232

Sun's true altitude, secant, - - -	0·01107
Ship's latitude, secant, - - - -	0·01122
Half sum, cosine, - - - - -	9·56440
Remainder for azimuth, cosine, -	9·86670
	2)19·45339
32° 12′ Sine =	9·72669
2	

True azimuth, - -	N.	64	24	E.
Magnetic azimuth, -	N.	70	36	E.
Variation, - - - -		6°	12′	W.

	H.	M.	S.	
Time from noon, - - - - -	4	41	55	
	24			
Apparent time at ship, - - -	19	18	5	
Equation of time, - - - -	+	3	17	
Mean time at ship, - - -	19	21	22	May 27.
Mean time at Greenwich, - -	19	49	20	"
Longitude in time, - - -		27	68 =	
		7°	2′ W.	

VI.—THE LOG BOARD.

The account of the ship's way, as kept at sea, is registered on a board or slate, called the log-board, or slate, which is usually divided into six columns. The first on the left hand contains the hours from noon to noon; the second and third, the knots and fathoms the ship has run in half a minute, or the miles, and parts of a mile, in an hour; the fourth, the ship's course; the fifth, the wind; and the sixth, the leeway. At noon of each day, insert into the log-book the different courses and distances, the differences of latitudes, and the different departures, to find the place of the ship, as directed in *Traverse Sailing*.

Great care must be taken to correct the several courses, for variations, leeway, currents, heave of the sea, remembering always to find the latitude and longitude by observation at every opportunity. If the latitude and longitude by the ship's reckoning disagree by observation, examine the several courses and distances sailed, and reflect whether the ship may not have been affected by winds, currents, or heave of the sea; and after proper allowance being made, if it agrees with the observation, you have then corrected the reckoning. But if they disagree, examine the log line and half-minute glass.* *Errors* often arise from the variation not being properly corrected, and bad steering. If the reckoning still disagree, take a number of observations, and find the mean of them; and on it the greatest reliance may be placed.

In many of the works on navigation there are rules given for correcting a ship's reckoning, but at best it is little better than guess work.

For those that may not be acquainted with a ship's reckoning, the following form of two days' work is from a journal of a voyage from Cape Clear to Cape Ortegal.

That it may be easily understood, the different courses are corrected for variation and leeway, although it is the general practice to put down the apparent courses, and correct them afterwards.

TWO DAYS' WORK, TAKEN FROM A JOURNAL OF A VOYAGE FROM CAPE CLEAR TO CAPE ORTEGAL.

April 12th.—At 2 p.m. received the chronometer, which was 41 seconds slow by Greenwich time, losing half a second each day. Hands engaged stowing and preparing for sea.

* In this Journal, each knot is divided into 10 fathoms of 5 feet each; or each knot equal to 50 feet, with a glass running out in 30 seconds: although many prefer a glass to run out in 28 seconds, with a knot equal to 48 feet, or 8 fathoms of 6 feet each.

Latitude of Cape Clear,	- - - -	51° 25′
Latitude of Cape Ortegal,	- - - -	43 46
Difference of Latitude,	- - - - - -	7° 39′
		60
In miles,	- - - - - - -	459
Longitude of Cape Clear,	- - - -	9° 30′
Longitude of Cape Ortegal,	- - - -	7 39
Difference of Longitude,	- - - -	1° 51′
		60
		111 miles.

What is the course to steer by middle latitude?

Latitude left,	- - - - - -	51′ 25′
Latitude in	- - - - - - -	43 46
Sum,	- - - - - - - -	95° 11′
Middle latitude,	- - - - -	47 35
Co-middle latitude,	- - - -	42 25

To find the Course.

As difference of latitude 459,	- -	2·66181
Is to difference of longitude 111,	- - -	2·04532
So is cosine of middle latitude 42° 25′,	- -	9·86855
		11·91387
		2·66181
To tangent of course, 10° 8′,	- -	= 9·25206

To find the Distance.

As radius,	- - - - - - -	10·00000
Is to difference of latitude 459,	- - -	2·66181
So is secant of course, 10° 8′,	- - -	10·00683
		12·66864
		10·00000
Distance,	- - - - - -	466 = 2·66864

April 13th.—A light breeze, with pleasant weather. At 7, the pilot came on board. At 9 unmoored; at 11 weighed anchor, with a light breeze from the west.

H	K.	F.	Courses.	Winds.	Leeway.	Remarks, Sunday, April 13th.
1	2					Light winds and clear weather.
2	2	2	S. ¾E.	W.		
3	2	6				Found the true bearing off Cape Clear from the ship to be W. by S. ½S.,
4	3					and the ship ran 3 miles, and the Cape bore W. by S. Distance from
5	3	5				the Cape 9¼ miles.
6	4					
7	4					
8	4	2				
9	4	5				
10	5					Fresh breeze and cloudy.
11	5		S. by E.	W. by S.		At 12 found the meridian altitude of the star Procyon, 44° 57′
12	5	2				
1	5	2				" zenith distance, - - - 45 3
2	5	5				" declination, - - - - 5 37
3	5	5				
4	6					" latitude, - - - - 50° 40′
5	6					
6	6	3				Set topgallant sails.
7	6	2				
8	5			W.		Found the latitude by the meridian altitude of the sun, 49° 46′.
9	5					
10	5					
11	5	3				
12	5					Longitude by observation, - - - - - 9° 2′.

Cape Clear being the last definite point of land in sight, the ship's latitude and departure are taken from it—latitude 51° 25′ N., longitude 9° 30′ W.

Courses.	Distance.	N.	S.	E.	W.
S. ¾E.,.........	30		29·7	4·4	
S. by E.,.....	83		81·4	16·2	
	Difference of latitude.		111·1	20·6	Departure.

Found the sun's amplitude to be	- - -	N. 76° W.
Observed amplitude,	- - - - -	N. 47 W.
Variation,	- - - - - - -	29° W.

Yesterday's latitude,	- - - - -	51° 25′ N.
Difference of latitude,	- - - -	1 51
Latitude by account,	- - - -	49° 34′ N.
Latitude distance from Cape Ortegal,	- -	459 miles.
Subtract	- - - - - - -	111 "
Latitude distance from Cape Ortegal,	- -	348 miles.
Yesterday's longitude,	- - - - -	9° 30′ W.
Difference of longitude,	- - - - -	0 32
Longitude by account,	- - - - -	8° 58′ W.

H.	K.	F.	Courses.	Winds.	Leeway.	Remarks, Monday, April 14th.
1	6	3	SSE.	W. by N.		
2	6	5				Wind brisk, with light, drizzling rain.
3	6					
4	6					
5	5	7				Carpenter painting and repairing the boats.
6	5	5				
7	5	2				
8	5					
9	5					
10	5					
11	4	6	S. by E. ½E.	W. S. W.		Light breeze.
12	4	4				
1	4	4				At 25m. to 2 p.m., found the latitude by the star Betelyncse to be 48° 32′.
2	4	3				
3	4					
4	3	5				Tried for current, but found none.
5	3	5				
6	3	2				Sun's meridian altitude, - - - - - - - 38° 34′
7	3	2				
8	3					" zenith distance, - - - - - - - 38 26
9	3		S. by E. ¼E.	Variable.		" declination, - - - - - - - - - 9 28
10	3					
11	3					The latitude by the sun, - - - - - - 47° 54′
12	3					The mean longitude by chronometer and observation, - 8° 10′

By the sun's azimuth at 6, found the variation to be 28°.

Courses.	Distance.	N.	S.	E.	W.
S.S.E..............	61		56·4	23·3	
S. by E. ½E.,...	38		33·4	11	
S. by E. ¼E.,...	9		8·7	2·2	
	Difference of latitude,		101·5	36·5	Departure.

Yesterday's latitude, - - - -	49°	34′
Difference of latitude, - - - -	1	41
Latitude by account, - - - -	47°	53′
Yesterday's longitude, - - - -	8°	58′
Difference of longitude, - - - -		54
Longitude by account, - - - -	8°	4′

Yesterday's latitude distance from Cape Ortegal, 348 miles.
Subtract - - - - - - - - - 101 "

This day's latitude distance from Cape Ortegal, 247

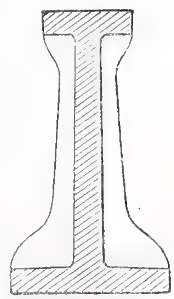
ON THE HISTORY AND CONSTRUCTION OF THE BRITANNIA BRIDGE.

By Mr. George Grove, Secretary to the Society of Arts.

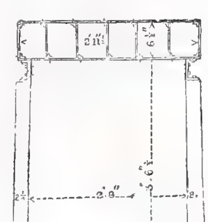
It was originally intended that the Chester and Holyhead Railway should cross the Menai Straits by Telford's well-known suspension bridge, but this plan was soon abandoned on account of engineering difficulties; and the site occupied by the present bridge fixed on. It takes its name from the Britannia Rock, lying in mid-channel, on which its centre pier is founded. At this place Mr. R. Stephenson proposed to build a bridge of two cast-iron arches, each of 350 feet span and 100 feet in height, which were to be erected without the use of centerings by continued additions to the spandrels, each piece being connected to its fellow on the opposite side of the pier by tie-rods. An end was put to this design by the requirement of the Admiralty that the same height should be preserved at the springing of the arch as at the crown; in other words, that its under side should be a straight line.

In this position of affairs the conception of a tube occurred to Mr. Stephenson; and, to determine its shape and the details of its construction, he was empowered by the directors of the line to make a magnificent series of experiments, which were conducted at the works, and under the care of Mr. William Fairbairn, at Millwall. The first series of experiments was on 34 tubes of three different sections, round, oval, and square or rectangular, varying in length from 18 to 27 feet, and in diameter from 9 to 18 inches. They were in all cases supported at their ends, the testing weight being hung at the middle, till fracture took place. The rectangular form was found to be much the strongest; it was the only one in which failure did not take place in the upper side.

When a beam supported at its ends is loaded at the middle, the fibres of the top, or upper side, are compressed, while those of the bottom are stretched. When, therefore, a beam of uniform shape is broken by the failure of the top, it is evident that the strength of the material to resist compression is not equal to that with which it resists tension: and the reverse. The power of cast-iron to resist compression is to its power of resisting tension as 5 to 1; therefore, girders of that material are made of the accompanying section; while by these experiments it was discovered that in wrought-iron the proportion is reversed, its power to resist compression being to its power to resist tension as 9 to 11.



The second series was on a model tube, one-sixth of the dimensions assumed for the real bridge, 75 feet long, 4 feet high, 2 feet 9 inches wide. The sides and bottom were of single plate; but the top contained six cells, or flues, running from end to end. Six experiments were made with this model, to determine the proper proportion to be kept between the material of the top and of the bottom. In the last experiment the tube broke with 86 tons suspended, equal to 172 tons distributed over its length; the sectional area of the top being $26\frac{1}{2}$ inches, that of the bottom $22\frac{1}{2}$, or as 11 to 9 nearly.



During these experiments the masonry of the bridge was proceeding rapidly.

The Britannia rock is in mid-channel: upon it is the tower called by its name, which at its base is 60 feet by 50 feet 5 inches. Its

entire height is 221 feet 3 inches. It is not of solid masonry, but contains a centre wall dividing it into two wells, which are arched over under the tubes at a height of 97 feet from the base. The sides are tapered, so that at the level of the bottom of the tubes it is 51 feet 4 inches by 45 feet 5 inches.

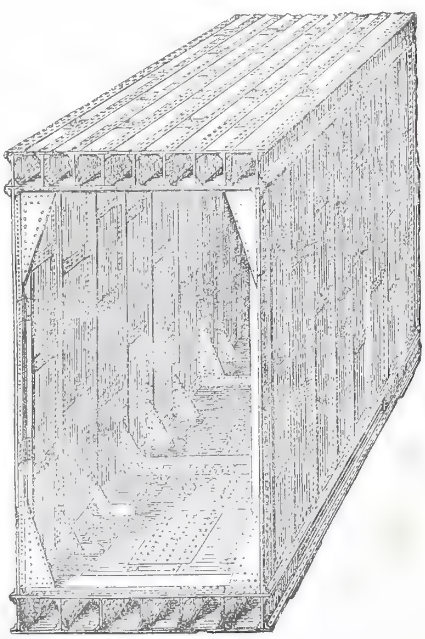
At a distance of 460 feet on each side of the Britannia tower stand the two land-towers on the Carnarvon and Anglesea shores. At their base they are 60 feet by 37 feet, and at the level of the tubes, 51 feet 4 inches by 32 feet.

From the land-towers to the face of the abutments, which stand still further inland, is a space of 230 feet. The abutments themselves are in all 176 feet long. Each entrance is guarded by a pair of gigantic lions, carved in limestone, from the design of Mr. Thomas. The external parts of the masonry are of "Anglesea marble," a hard mountain-limestone, full of fossils, extremely durable, and with an appearance of great solidity. Some of the blocks are of enormous size: those over the tubes in the land-towers are 20 feet long, 2 feet 2 inches deep, and about 3 feet wide, weighing about 7 tons. This stone is backed in with Runcorn red sandstone, and with brickwork in cement.

A large number of cast-iron girders is built into the solid stonework, for the purpose of effectually distributing the pressures of the enormous weights which are carried by certain spots during the lifting of the tube. Of these the Britannia tower contains no less a weight than 394 tons, the total weight in the towers and abutments being 929 tons.

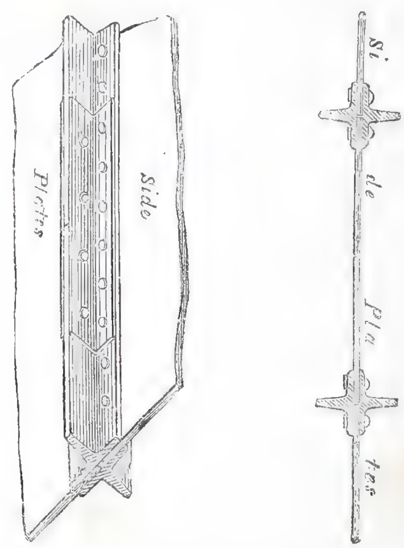
The scaffolding employed was constructed on the modern plan, with whole balks of very large timber.

The dimensions of the tubes having been definitely fixed, it was determined to build the four large ones on platforms or jetties lying along the high-water mark of the Carnarvon shore; then to float them to the foot of the towers, and finally raise them to their places by hydraulic power. The land-tubes must be built in their places on scaffolding.



We will suppose one of the large tubes to be completed, and lying ready to be floated on the platform. It is 472 feet long, 3 feet higher at the end which is to enter the Britannia tower than at the other, which is 27 feet high. It has eight cells in the top, and six in the bottom; in both cases 1 foot 9 inches high, but of different width. The platforms forming the upper and lower sides of the top cells are of single thickness; they are connected with the upright plates of the cells by two angle irons, (of similar section to the accompanying sketch,) matched on the opposite side of the plate by a flat strip. These junctions are formed by rivets, which are inserted at a red heat, and while hot are closed up, exerting by their contraction a great power on the plates through which they pass. The riveting of the lower part of the top cells is performed with ease, before the top platform is put on; but to accomplish the riveting of the latter, it is necessary that the "holder-up" (the man who keeps the rivet in its place whilst its head is being beaten up) and his boy should be inside the cells, which they are for hours together. While in this position, the rivets are supplied to them through small holes left for that purpose.

The plates forming the sides run vertically; they are joined together by double T irons, which form a pillar of great strength at every two feet distance throughout the tubes. These T irons are bent round at right angles, and riveted to the platforms of the top and bottom, and a triangular plate, called a gusset, is used to fill the corners, with great effect against the twisting strain exerted by the wind. The platforms of the bottom cells are of double thickness of plates, arranged so as to break joint, the covers (plates riveted over the joints) being large and strong; the whole forming, in fact, a *chain* to resist tension, while the top is constructed with small covers and nicely executed joints, so as to act as a *pillar* to resist compression. The sectional area of the "top" of the tube at the Britannia tower is 648; that of the "bottom," 585 square inches.

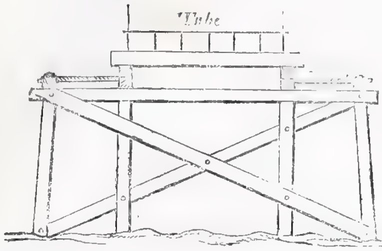


Cast-iron frames of great strength are fitted into each end of the tubes, and into the lower set of cells, to resist the great crushing or "shearing" strain occurring at the points of support in the towers. To these frames are fitted the iron beams to which the lifting chains are subsequently attached, and which consist of three very strong cast-iron girders accurately fitted, having pillars of iron jammed between them, and a strap of wrought-iron passing completely round them, so as to make them all into one solid mass.

The tubes having been completed on the platforms (see annexed sketch), it was necessary that they should be cut away, that room might be made for the pontoons, by which the work of transport was to be done: temporary stone towers were built under each end, and a packing of elm planks inserted to receive the pressure of the tube. The platforms had been built with an upward curve of 9 inches; and it was found that, after they were cut away and the tube took its own bearing, the deflection only slightly exceeded this.

The rocky beach beneath the tubes was next excavated, to admit the pontoons. These were eight in number—six of wood, 100 feet in length, 25 feet wide, and 10 feet deep; and

two of iron, of the same length, but 31 feet wide and 8 feet 9 inches deep. They were arranged below the tube in two groups. Each pontoon is divided by partitions, or bulkheads, into several compartments, each having a valve, which can be



shut or opened by screws on deck, and by which any amount of water can be admitted, and the buoyancy thereby diminished or wholly destroyed; and there are also in each one, pumps for removing this water, or any that may leak in. By keeping these valves open, the pontoons remained perfectly still below the tube till the time came for floating.

"The broad principle on which it was determined to conduct the floating of the first tube was, that the tube should be hauled out into the flowing or rising tide, which runs in the required direction, when the velocity of the tide was such as to bring the tube to the foot of the piers just at the time of high water; the ends of the tube being brought over stone shelves, prepared at the bases of the towers, on which, as the tide descended, it would be left resting. Thus, the tide itself was made to do the work of transport; no exertion would be wanted, except for the purpose of pilotage."

The difficulties which had to be guarded against were enormous. A mass of 2000 tons in weight, and of the most cumbrous awkward shape imaginable, had to be navigated in a tideway where the current is often eight miles per hour, with the risk of a capricious wind springing up, (as in every mountainous country they unexpectedly do,) which would act with fearful effect on the huge sail-surface of the tube. This unwieldy mass had to be turned half round on its passage, and guided safely past the points of the Britannia Rock; and lastly, there was the absolute impossibility of making any change in the arrangements, as unforeseen emergencies might occur.

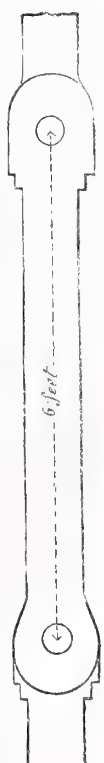
"Two 12-inch ropes are laid down the stream from a sunk mooring opposite the farthest tube, to two capstans on the other side of the Anglesea land-tower; on them the tube is to travel as a ferry boat on its guide lines. They run over the pontoons, where they pass through cable stoppers, which are contrivances by which the rope can be on occasion gripped so hard as to stop the motion of the whole mass. These guide lines are buoyed up by casks attached at intervals, so that they may not be cut by the sharp rocks of the bottom. Two 8-inch lines lead from moorings on the opposite shore to capstans on the pontoons, for the purpose of hauling the tube out into the stream; five other lines lead to powerful capstans on the shores and on the Britannia Rock, by which the last delicate operation of placing the tube in its ultimate position may be effected.

"These capstans were fully manned by 11 superintendents, 450 labourers, 65 sailors, and 12 carpenters. Each capstan had 48 men; each set of pontoons carried 105 hands; and six boats, with spare line, attended the tube in its outward progress. The capstans were signalled to from the tube by holding up the distinguishing letter of the capstan and a flag, the colour and position of which indicated what was required."

On the evening of the 20th of June the floating took place. The pontoons having been rendered buoyant by the closing of the valves, rose with the tide until they reached the bottom of the tube, which was lifted clear off the temporary piers at half-past seven. The land attachments being cast off, and the capstans of the hauling-out lines set in motion, the mass swung out into the stream at a rapid pace. When the proper distance from shore had been reached, a chain made fast to the back of the tube was cast off, and the onward progress began. By means of the cable-stoppers, which acted admirably, the speed was kept at about $1\frac{1}{2}$ miles per hour. When about three-quarters of the journey had been performed, and the tube had begun to take a position close to the Britannia Rock and oblique to the course of the tide, a delay arose, owing to an accident at the "Llanfair Capstan," on the Anglesea shore, where the coils of the rope overrode one another, and prevented the motion of the capstan; as the tube, therefore, floated on, it dragged the capstan from its frame, making the bars spin round, and knocking down the men. And had not the superintendent of the capstan induced the crowd of lookers-on to take hold of the long end of the rope, and thus by the weight of hundreds prevented its further slipping, there is much cause to fear that the pontoons would have grounded on the Britannia Rock, and the whole have been wrecked.

The key to the concluding steps of the floating was a pile of timber and stonework beyond, but close to, the Anglesea land-tower, called the "Anglesea Butt:" against this, as a pivot, the tube was to bear while being veered across the opening, at right angles to the line of the current. Up to this it was hauled by a powerful crab behind the Butt; after which the delicate operations necessary for inserting the high end into the recess in the Britannia tower (only two inches wider than the tube in its oblique position) were performed by the two capstans and the large crab on the Britannia Rock. The tube having been hauled home at the Britannia tower, it only remained to bring it into the open recess in the land-tower, which was done at twenty-two minutes past nine, when the welcome "All right!" of Mr. Stephenson was the signal for loud and prolonged cheering and firing of cannon. As the tide ebbed, the pontoons floated away from below, leaving the tube to span the opening with no real or imaginary assistance.

The tube having reached its destination at the foot of the piers, the next operation was to lift it through the 100 feet between that position and its ultimate place. This was done by hydraulic presses of enormous dimensions. That at the Anglesea end, of the construction and casting of which we have given a full description, with illustrative plate, in Vol. I. p. 224, had a ram of 20 inches diameter, and a cylinder 10 inches thick; the other at the Britannia end, two cylinders, with rams 18 inches diameter. The ram carried a cross-head of prodigious strength of cast-iron, strengthened on the top side by wrought-iron links put on hot: from it depended the lifting chains, the lower ends of which were secured to the beams in the end of the tube. The "stroke" of the press, or the height which it is capable of lifting through, is six feet, which is also the length of each link of the lifting chains. These are formed like those of a suspension-bridge, alternately of eight and nine bars of the annexed form. On the upper part of the frame of the press, 12 feet below the top of the cross-head when at the highest point of its lift, is an arrangement of "clams," which are blocks of iron placed accurately to fit the square shoulders of the head of the chain: by screws and gearing these clams can be opened or closed, so as to let the chain pass, or to embrace and hold it firmly. On the cross-head is a precisely similar arrangement. When, therefore, the press has completed its lift of six feet, the head of the third link has just reached the level of the clams. These being brought in under the shoulders of the link, transfer to themselves the weight of the dependent tube; the clams on the cross-heads are then opened; the ram lowered, the top link taken off; the cross-head clams are closed, and the bottom clams opened; when all is ready for another lift of six feet.



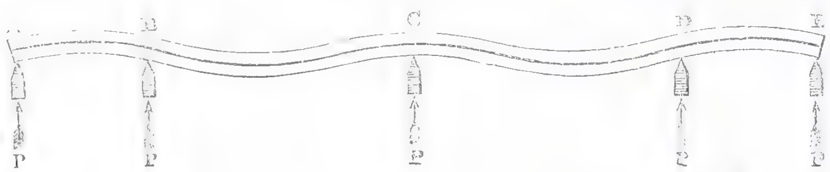
The whole of this ponderous machinery was supported on beams of wrought-iron, of immense strength, which span the tower above the tube.

The time occupied in making each lift of six feet was about 38 minutes. The precaution was taken to underbuild the tube with brickwork in cement, filling up the recess in the towers. During the lift, a packing of thin wood was introduced between

the top of the brickwork and the bottom of the tube, that in case of accident an inch might be the greatest distance fallen through. That these precautions were not needless was shown on the 17th of August, when the bottom of the cylinder of the single press broke, and allowed the tube to descend on to the packing. No serious injury was done to the tube, though the delay in procuring a new cylinder was considerable. On the 13th of October, the full height was reached.

The advantage derived from *continuity* by a beam like the entire tube of the Britannia Bridge is very great. If a beam be supported, as in the present case, at five points, it will take a curve, of which the figure is an exaggerated representation; and the deflection of the spans, B C, C D, is less than half what it would be if the connections at B, C, and D were removed, and the beam existed in four independent short pieces. This advantage was obtained in the Britannia Bridge as follows:—

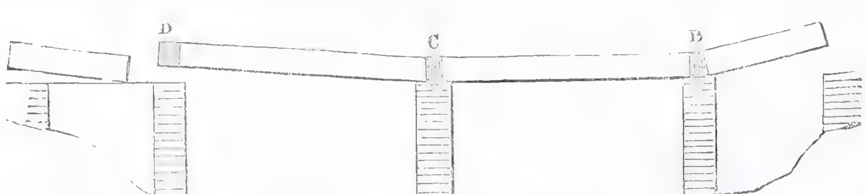
The two large tubes of one line being raised, and the land tubes completed on their scaffoldings, the end of the small tube, A, was raised to $14\frac{1}{2}$ inches, and while in this position united



at B to the next large tube. The end A was then lowered, when the centre of the large span was found to be lifted two inches. The junction between the two large tubes in the Britannia tower was next made, the end D being raised $31\frac{1}{2}$ inches. On its being lowered, the centre of B C was found to be lifted $1\frac{1}{2}$ inch, while the deflection of D C was found to be $2\frac{1}{2}$ inches less than it had formerly been, owing to the reaction exercised on it by the spans B C, A B. Lastly, the land tube D E was joined, its outer end being raised $14\frac{1}{2}$ inches, and its lowering producing the same effect on D C that the corresponding operation had on B C. In this manner the whole tube became a continuous beam; and the effect is very nearly the same as though it had been constructed in one length and placed complete on its place. That length is 1,512 feet.*

The expansion and contraction of such a length of metal is considerable, even under ordinary changes of temperature. Its effects are rendered more manageable by allowing the tube to rest in the Britannia tower, and to expand outwards in both directions, there being arrangements of rollers, &c. in the land towers and abutments to facilitate its motion. The greatest motion observed in each half hitherto is $3\frac{3}{16}$ inches. By a simple arrangement of clockwork moving a ruled paper (the tube itself carrying a pencil), a daily register is kept.

The second tube was floated on the 4th of December, and lifted to its place on the 7th of January, 1850. The last of the land tubes of the first line was lowered to its place on the 4th



of March, and on the 5th, Mr. Stephenson and staff passed through with a monster train drawn by three locomotives.

Ten days after this, the line was tested by the government inspector, with a train of 434 feet long, causing a deflection of not $\frac{3}{4}$ inch.

The third tube was floated on the 10th of June, and deposited on its permanent bed on the 11th of July. The fourth tube was floated on the 25th of the same month, and placed on the 12th September.

The following statistical facts will be interesting:—

The total weight of the tubes is nearly 11,000 tons, being greater than that of four 120-gun ships, with their crews and stores on board. This weight is made up of 9,360 tons of wrought-iron, and more than 1,200 tons of cast-iron and timber. They are composed of about 186,000 separate pieces of iron, pierced by more than 7,000,000 of holes, and united by upwards of 2,000,000 of rivets, the angle and T iron being not less than 83 miles in length. The weight of the lifting chains alone, at each end of the tube, was more than 40 tons, which, with the cross-head and ram of the press, made a total of more than 60 tons to be lifted before any effect could be produced on the tube itself. Of the masonry in the towers and abutments, there were about 1,500,000 of cubic feet, which would form a pyramid whose base would equal the central area of Leicester Square, with a height of 80 feet; the weight in all 150,000 tons. Allowing twelve working hours in the day, and six days in the week, this masonry was prepared and laid at the rate of three cubic feet per minute during the whole time of its construction.

The resident engineers to whose charge Mr. Stephenson confided the execution of the masonry and iron work, were respectively Mr. F. Forster and Mr. Edwin Clark. The designs for the masonry were by Mr. Francis Thomson.

One of the tubes was constructed by Messrs. Garforth, the remainder by Mr. Charles Mare. The hydraulic presses and lifting arrangements were elaborated by Messrs. Easton and Amos. The contractors were Messrs. Nowell, Hemingway, and Pearson.

BUSSE'S IRON BRIDGE.

THE system of bridge building advocated by Mr. Busse, and illustrated in the plate accompanying this article, may, for practical purposes, be considered as a perfect novelty, and deserving of thorough examination. The principle involved, is the construction of large spans out of sheet or flat iron, bolted together so as to oppose their edges to the strain coming upon them. Our plate represents, in fig. 1, a full elevation of a railway viaduct on this principle; it is understood to be thrown across a wide and deep ravine, such a one indeed as we are not often accustomed to meet with in railway or highway engineering. Fig. 2 is a side elevation of the central supporting pillar, which is of a pyramidal form; fig. 3 is a transverse section of this pillar, and fig. 4 is a detailed view of the method of joining together the flat plates employed in its construction. The entire span of the bridge here represented is 600 feet. The depth from the underside of the carriage way is 400 feet. The three supporting pillars are respectively 300, 100, and 50 feet in height. A reference to the plate will show that two separate thoroughfares are contemplated in the design; that is, an upper railway for a railroad, and a lower gallery for ordinary traffic. The supporting pillars, as previously observed, are constructed of flat rolled iron plates, the area at the base is 66 × 40 feet, and at the upper end 25 × 6 feet. The computed weight of such a pillar is from 5 to 6000 cwt., and it may be erected in six months. If placed on a rock foundation, no other support than the rock is required; if on sand or other softer material, 62 piles will give the necessary support. In the latter case, on each of the piles are placed four perpendicular pieces of 6 inch angle-iron $\frac{1}{4}$ inch thick. These primary pillars serve as the fundamental support for the ribs or bars of iron afterwards fastened to them.

* The entire length of the bridge is 1,832 feet 8 inches; considerably more than that of Waterloo Place, from the York Column to the foot of the Quadrant. The height of the balcony of the York Column is nearly that of the under side of the tube above high water.

ILLUSTRATION OF MECHANICAL DRAWINGS.

SECTION THIRD.

THE DELINEATION OF ENGINEERING SUBJECTS.

Under this head we propose merely to give a few diagrams, illustrative of the method of finishing drawings of various subjects, which come within the denomination of civil engineering, or engineering drawing. It is evident that the same system of copying the outlines of engineering subjects, as bridges or the "bases" and "caps" of the engine chimney shafts, which we have already elucidated in connection with mechanical and architectural subjects, will be available in this department. We, therefore, do not deem it necessary to take up space by giving elementary examples, contenting ourselves by simply showing how various parts of engineering drawings are generally delineated.

In fig. 133, the method of representing a river on a map is shown: *a a* the river, *b b* the banks, *c c* small springs flowing into the main stream. In fig. 134, the method of representing "hilly" ground or a range of hills is shown. In fig. 135 the method of representing "rocks," as used in marine maps, &c., is given. In fig. 136 we show the way in which the "ground" connected with a sectional drawing is shown.

Fig. 133.

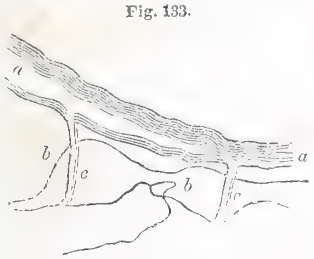


Fig. 134.

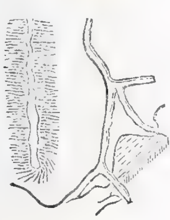
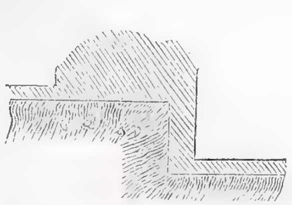


Fig. 135.

In concluding the three preliminary departments of "Mechanical Drawing," we trust that we have presented a collection of examples which will be of practical service to the reader, in enabling him readily to commit to paper any "ideas of invention" which may be floating in his mind, as well as to copy with facility and neatness the production of others. We have aimed more at presenting examples useful in themselves as lessons, than to give those which might be merely attractive in their appearance. We now proceed to the important department of the preparation of working drawings—a department in which the pupil will find the benefit of having attended to our preliminary examples.

Fig. 136.



SECTION FOURTH.

PRACTICAL GEOMETRY AS APPLICABLE TO THE PREPARATION OF WORKING DRAWINGS AND LINES, USEFUL IN CARPENTRY, MASONRY, JOINERY, AND MECHANICS.

The knowledge which is principally required in "laying down," as it is termed, "working drawings," useful in the various operations of carpentry, masonry, and joinery, is that species of practical geometry having relation to the sections of solids, the development of their surfaces, and the sectional delineation of their solid angles.

In the carpentry of a dome, the skeleton framework consists of isolated ribs or rafters, whose vertical outlines would represent the sections of the convex and concave surfaces of the shell of which the hollow globe is composed. These rafters are stayed by portions placed horizontally in a direction everywhere at an equal distance from the base of the hemisphere.

To divide the concave surface into panels.—In the first place, determine the number of the tiers of panels into which the vertical section of the concave surface is to be divided. Then lay down a development of the concave surface, or of such a portion as may be deemed necessary for one compartment of panels only, according to the nature of their proportions. Upon this assumed division, or outline sketch, put the size of the panels for one compartment only. This being done, proceed to try how far the proportion of the compartment thus assumed will, by being repeated, agree in filling up the whole concave surface of the dome. Should the approximative space assumed for one compartment only be found either too large or too small to constitute an aliquot part of the whole surface, the original sketch must be increased or diminished accordingly, in order that the total number of compartments may be of such dimensions as may approach nearest the answered proportions of the first compartment first sketched out.

In fig. 3, Plate A, "Building Arts," we explain the development of one of three compartments, taken upon the curved rib, as shown by the dotted line, A B, in fig. 2. The length of this line is carefully ascertained by dividing the whole distance from A′ to B′ into any number of equal parts. In the present instance, we have divided the whole into parts, numbered from 1 to 8. From each of these points draw the plumb lines, A *a*, 1 *b*, 2 *c*, 3 *d*, 4 *e*, 5 *f*, 6 *g*, 7 *h*, 8 *i*, cutting the seat of the curved rib in the points, *a b c d e f g h* and *i*, upon the plan, fig. 1. Then, with the point, *o*, as a centre, describe the circular dotted lines, *a k*, *b l*, *c m*, *d n*, *e o*, *f p*, *g q*, *h r*, *i s*. In fig. 3, make the length of the line, A′ B′, equal to the length of the curved rib, as shown by the line, A B, fig. 2, with its corresponding number of parts (equal) from 1 to 8. Through these points draw at right angles the lines, *a k*, *b l*, *c m*, &c.; make their lengths respectively equal to the lines, *a k*, *b l*, *c m*, in fig. 1. Through the points, *a b c*, draw the curved line, *a i*, and through the points, *k l m n o*, &c., draw the curved line, *k i* which forms the boundary of the compartment. In the design in Plate A, there are sixteen compartments of three panels each, occupying the whole surface of the concave surface.

To form the purlins in a dome roof.—Let A′ B′ C′, fig. 5, Plate A, represent the plan of the roof; A B C its section, in which the position of the purlins are placed. The sectional lines of the figure, *a b c d*, represent the substance of the timber required for the squaring of the purlin, the dotted parts representing the superfluity required to be cut off. The radii of the purlins are shown by the lines, *g q*, *h p*, and *k o*, *m n*.

The purlins of the dome, as shown in fig. 4, are formed after this manner, according to their respective diameters, and are joined to the ribs by mortice and tenon, and bolted also, as shown. The explanation of the constructive parts of the example in Plate A, is given in the article entitled "Building Arts," under the head of "Carpentry." Wherever two cylindric surfaces meet each other, or where a cylindric arch is made to intersect with an arch consisting of the segmental portion of any other arch, the intersection of both these surfaces is called a "groin," and the quoins of the mitre formed thereby are made to consist of the marked portions of the wedge-formed solids which constitute the component parts of both the arches.

In Plate B we show the mode of bringing down the moulds for the formation of the quoins of the masonry in a groin formed by the intersection of a cylindrical arch with the segmental portion of a spherical arch. The chord line of the spherical arch, or the diameter of its springing line, and the versed sine or the height of the crown of the intrados, being determined, the length of the radius for describing the curve of the arch is next wanted. This may be obtained by dividing the sum of the squares of the half chord and versed sine by twice the versed sine. The quotient is the length of the radius required.

Example.—Let us suppose the diameter of the springing line shown in the engraving to be 18 feet, and the height of the arch 2 feet 6 inches above the level of the springing line; then $\frac{9^2 + 2{\cdot}5^2}{5} = 17{\cdot}45$ feet = the radius for the curve of the arch.

Having described the curve of the intrados of the spherical arch, divide it into the number of arch stones required, as shown by the points, a', a', a', &c. Next proceed to lay down the curve of the intrados of the cylindric arch in the position shown. Draw the intradosial arras lines, a, a', a, a', &c., parallel to the springing line, cutting the curve of the cylindric arch in the points, a', a', &c., and from the points, a, a, a, &c., in the curve of the spherical arch draw the perpendicular lines, $a\ c$, $a\ c$, &c., cutting the diameter of the spherical arch in the points, c, c, c, &c.; then, with the point, O, as a centre, describe the circular lines, $c\ b$, $c\ b$, &c., and from the points, a', a', a', &c., in the cylindric arch draw the perpendicular lines, $a'\ b$, $a\ b$, &c., cutting the circular lines, $c\ b$, $c\ b$, &c., in the points, b, b, b, &c., through which draw the curve line, F O. These form the mitre lines of the groin projected upon a horizontal plane passing through the springing line of the arch.

To find the plan-moulds for any of the quoins, say that of No. 4, let $a'\ k$ and $a'\ i$ form the section of one of the stones in the cylindric arch, and $a\ l\ a\ o$ form the section of its corresponding course in the spherical arch. Let $d\ b$ and $b\ g$ represent the length of the quoin on the intrados of the groin; then draw the line, i and h, intersecting the circular line, $n\ h$, in the point, h, and draw $d\ e$ at right angles to $d\ b$, $g\ f$ radiating towards the centre, O, the figure, $d\ e\ h\ f\ g\ b\ d$, is the outline of the plan-mould or size of the stone required for the quoin, No. 4. The moulds, $a\ a\ i\ k$ and $a\ a\ l\ o$, with their circumscribing squares, $r\ s\ t\ u$ and $p\ q\ v\ w$, show the angle of inclination at which the moulds are applied on the ends of the block of stone, which is previously worked to the plan-mould, $d\ e\ h\ f\ g\ b\ d$.

To draw the working moulds for the voussoirs and the quoin heads of an oblique arch, where A K C L, fig. 1, Plate C, represents the abutments of a cylindric arch, with spiral belts and joints, and B C the obliquity of the arch, and the circles, E′ A′ B′ F, the thickness of the wings that compose the arch.

Lay down the development of the intrados and extrados of the arch, as shown by the diagram, fig. 4, of the coverings of solids. Let the curvilineal lines, A, C, K, L, fig. 2, represent the boundary lines of the development of the intrados, and N, E, m, I, the development of the extrados, taken according to the thickness of the ring, A′ E′, or B′ F′, in fig. 1. Draw the straight line, A C, in fig. 2. From the point, K, let fall the line, K n, perpendicular to the line, A C; divide the line, A n, into the most convenient number of equal parts for the arch stones, and subdivide the line, n C, into the nearest number of equal parts which may approximate to the size of those on A n. Let o, n, q, r, and s, represent the divisions on the line, A n. From the points, o, p, q, r, draw lines parallel to n K, and cutting the line, A K, in the points, 1, 2, 3, 4; at right angles to A K, draw the line, 1 5, 2 6, 3 7, and 4 8; let the line, $t\ m$, be produced, cutting the lines, A K and L C, when produced in the points, v, x; draw also the lines, $x\ y$ and $v\ u$, perpendicular to A K and L C, the line, $x\ v$, will be the development of the intradosial arris, $y\ u$ will be the extradosial arris of the coursing stones; draw the remainder of the extradosial arrises, e 9, f 8, g 7, h 6, &c., parallel to the line, $u\ y$; draw also the heading joints, b, b, b, b, &c., of the intrados; the position of the extradosial heading joints are drawn to lines from a to 10·6, to 11·7, to 12, &c., as shown by $a\ a$, $a\ a$, $a\ a$, &c.

To find the bed-mould for the coursing joints.—Let A′ H′ B′, in fig. 3, be the right section of the cylinder of the arch, or the centre upon which the arch is turned. In fig. 2 take any point, H, in the central line of the development of the intrados, draw the perpendicular, H b and H t, cutting the line, $v\ x$, in the points, b and t. In fig. 3, make the length of the arcs, H′ b and H t, respectively, equal to the lines, H t and H b, in fig. 2. In fig. 3, draw the perpendicular lines, $b\ u$ and $t\ v$. From the line, H H, in fig. 2, draw the lines, H u and H v, perpendicular to H H, cutting the lines, $b\ u$ and $t\ v$, in the points, u and v; draw the line, H z, make $z\ x$ equal to H c, and through the points, u, x, v, draw the circular line, $u\ x\ v$, which is the curvature for the coursing joints or beds; make $a'\ b$ equal to the thickness of the ring stones; also make $b\ b$ equal to the length of one of the coursing stones, as shown on the development of the intrados; draw the lines, $a'\ b$ and $a'\ b$, to radiate towards the centre of the curve, and the mould lines are obtained.

To find the mould for the heading joints.—Draw the perpendicular line, P w, cutting the line, $t\ v$, in the point, w. Draw the chord line, $u\ w$; make the versed line, $s\ t$, equal to H c, and through the points, u, t, w, draw the circular line, which is the curvature of the heading joint; make the length of the circular line, $b'\ b$, equal to the line, $b\ b$, in the development of the intrados; draw the lines, $a'\ b$ and $a'\ b$, to radiate towards the centre of the circle, and the mould is obtained.

The angle for the twist of the beds is shown by the lines, $x\ u$ and $r\ y$, in fig. 2, from which the rules are drawn. By referring to the plate, the mode here shown is sufficiently clear without further explanation.

To find the bevels for the quoin heads.—Let b, b, b, &c., fig. 2, represent the first heading joint of the intrados from the face of the arch, and a, a, a, &c., the corresponding points of extrados of the same joint. Then, in fig. 3, produce the line of curvature of both the arcs of the intrados and extrados from a' to G and b' to F; let $a\ b$, in fig. 3, represent the heading joint; transfer the distances from $a\ c$, in fig. 2, to $a\ c$, in fig. 3, and $b\ l$, in fig. 2, to $b\ l$, in fig. 3. Join $b\ l$, and the line, $b\ l$, forms the angle of the face with arris of the intrados. The remainder of the bevels for the quoin heads to be obtained in a similar manner; thus, $d\ m$, in fig. 3, will be the bevel for the joint head, $d\ m$, on the drawing, fig. 4, and so on until the whole of the bevels are obtained.

To draw the scroll of the curtail step and hand rail for stairs.—In the full size scroll, let the circle, $a\ c\ d\ e\ b$, fig. 138, be four inches diameter. Within the circle describe the square, $c\ b\ e\ d$, and draw the diagonals, $c\ e$, $b\ d$. Divide the side, $b\ e$, into two equal parts in the point, 1. Parallel to $e\ c$, draw from 1 a line, 1 $k\ h$, and parallel to $b\ d$ draw 1 $m\ i$ 2. Divide a 2 in two equal parts; in the point, 5, draw 5 7; make 7 3 equal to a 2; join 3 4 parallel to 7 5. Divide 7 5 into two equal parts in the point, 6; draw a line from this parallel to 5 4; divide 7 6 into two equal parts, and set one of these from 6 to the point, 8, on the line, 6, &c. From the point, 8, as centre, with 8 d as radius, describe an arc, making the line, 6 8, produced in the point, c'. From the point, 6, with 6 c' as radius, describe an arc meeting the line, 6 7, produced in e. From the point, 5, with 5 e as radius, describe an arc meeting the line, 5 2, produced in the point, f. From the point, 4, as centre, with 4 f as radius, describe the arc, $f\ g$, meeting the line, 3 4, produced in g. From the point, 3, with 3 g as radius, describe an arc, $g\ h$, meeting the line, 7 1, produced in h. From the point, 1, with 1 h as radius, describe the arc, $h\ i$, meeting the line, 2 1, produced in i. Let off the width of rail from i to j. From the point, 1, with radius 1 j, describe an arc, $j\ k$, meeting the line, 1 h, in k. From the point, 3, with 3 k as radius, describe the arc, $k\ d$. The above operations will give the outline of scrolls for hand rail. The outline of the "curtail step" is produced from the same centres. Let m be the projection of curtail step, from the line of scroll, j. From the point, 1, with radius 1 m, describe an arc to x. From the centre, 6, with 6 x, describe an arc, $x\ n$. From the point, 5, with 5 n, describe an arc, $n\ o$. From 4, with 4 o, an arc to p; and from 3, with 3 p, to q.

In these hand rails the scroll is supposed to lie horizontally. In fig. 1, Plate D, the "scroll" there delineated hangs vertically, the "newel" being at the point, m, the hand rail being at B.

Let $a\ b$ be the height of the scroll. Divide it into seven equal

parts. Bisect the space between the fourth and fifth of these into two parts in the point, *c*; through *c* draw a line at right angles to *a b*. Make *c d* equal to a division on *a b*. Bisect *c d* in *e*; draw a line, *e o*, at right angles to *d c*. Make *d f* equal to *d e*; join *f g* parallel to *d e*. Bisect *f g* in the point, *h*; make *f i* equal to *h f*; join *i k*.

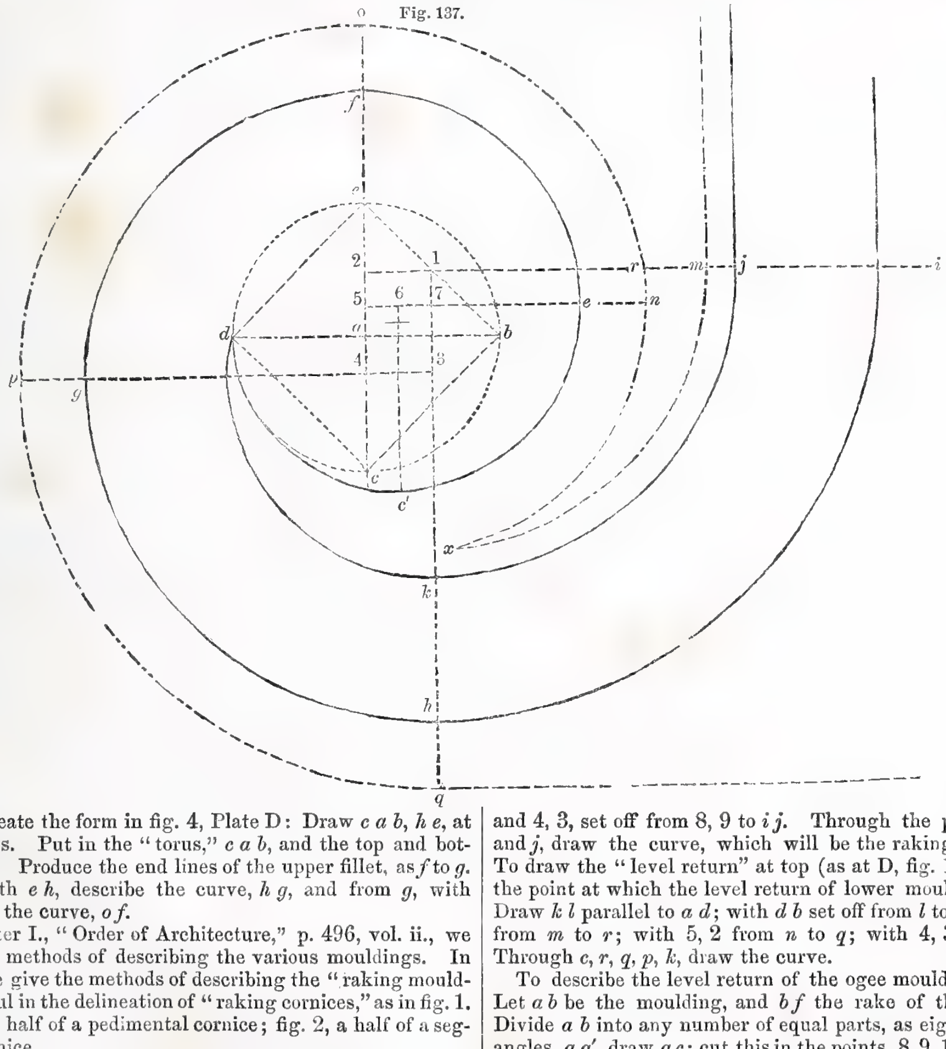
From the point, *c*, as centre, with *c a* as radius, describe the arc, *a l*. From the point, *d*, with *d l*, describe the arc, *l m*. From the point, *i*, with *i m*, describe the arc, *m n*. From the point, *k*, with radius *k n*, describe the arc, *n o*; and from *g*, with *g o*, the arc, *o p*. From the centre, *c*, with radius *c p*, the arc, *p q*. To describe the curve joining the hand rail with scroll: Draw the line, *a s*, at right angles to *a b*. Divide the distance, *a r*, *r v*, of the side, *r t*, of the pitch board, *s t r*, into equal parts, as five. From the point, *v*, on *r t*, draw lines through the points on *a r*; and from the point, *a*, draw lines through the points on *r v*. Through the points obtained by the intersection of the corresponding lines, draw by hand the curve, *a v*.

To describe the outlines of "hand rails," as in fig. 2, 3, and 4, Plate D

To delineate the form given in fig. 2: Put in the "quirked bend," *a b*. Measure from *b* to *c*; draw through this a line parallel to *b*. From *c* measure to *d e*; from these points describe the semicircles, *e i*, *d m*. Parallel to *b c*, from *e d* draw lines, *e g*, *d f*. From *g* and *f*, with radii equal to *e i*, *d m*, describe quadrants, *i h*, *m n*; join *n o*; *h p*. From *d* and *e*, with radius *d e*, describe arcs cutting in *r*. From *r*, with *r t*, describe an arc, *s t*.

To delineate the form given in fig. 3: Draw two lines, *d c e*, *n a*, at right angles to each other. From *c* measure to *d* and *e*, and from these points describe semicircles; produce lines from the centre of these parallel to *a n*, and from *f* describe a quadrant, *f g*; produce these lines to cut *b* as at *h*; from *h* describe a quadrant, *h i*; join *i j*. Bisect *i j*, bisect *i o*, and from *k* draw through *o* a line cutting *a m* in *n*. From *k* describe the arc, *i o*, and from *m* the arc, *o n*.

Fig. 137.



To delineate the form in fig. 4, Plate D: Draw *c a b*, *h e*, at right angles. Put in the "torus," *c a b*, and the top and bottom fillets. Produce the end lines of the upper fillet, as *f* to *g*. From *e*, with *e h*, describe the curve, *h g*, and from *g*, with radius, *h e*, the curve, *o f*.

In Chapter I., "Order of Architecture," p. 496, vol. ii., we have given methods of describing the various mouldings. In Plate E, we give the methods of describing the "raking mouldings," useful in the delineation of "raking cornices," as in fig. 1. Fig. 1, B is half of a pedimental cornice; fig. 2, a half of a segmental cornice.

To draw the "raking moulding" of the "cyma-recta," fig. 3: Let *a b* be the outline of the moulding, and *b c* the "rake" or slope of the pediment or roof. Divide *a b* into any number of equal parts, as 1, 2, 3. From *a* draw *a d* at right angles to *a a*; at right angles to this, from the points, 1, 2, 3, draw lines cutting *a d* in 4, 5, 6. Parallel to *e d*, *c b*, from the points, 1, 2, 3, *a*, draw lines, as 1 *r*, 2 *g*, 3 *p*, *a k*. Let the "raking moulding" begin at the point, *e*; draw *e f* at right angles to *b c*. From *d* measure to *b*; set this off from *f* to *g*. From 6 measure to 1, and set this off from 7 to *h*; with distance, 5, 2, and 4, 3, set off from 8, 9 to *i j*. Through the points, *g*, *h*, *i*, and *j*, draw the curve, which will be the raking cyma-recta. To draw the "level return" at top (as at D, fig. 1): Let *k* be the point at which the level return of lower moulding begins. Draw *k l* parallel to *a d*; with *d b* set off from *l* to *c*; with 6, 1 from *m* to *r*; with 5, 2 from *n* to *q*; with 4, 3 from *o* to *p*. Through *c*, *r*, *q*, *p*, *k*, draw the curve.

To describe the level return of the ogee moulding at fig. 4: Let *a b* be the moulding, and *b f* the rake of the pediment. Divide *a b* into any number of equal parts, as eight. At right angles, *a a'*, draw *a c*; cut this in the points, 8, 9, 10, 11, 12, 13, by lines from 1, 2, 3, 4, &c., on *c b*, parallel to *a a'*. From 7, 6, 5, 4, 3, 2, and 1, on *a b*, draw lines, 7 *p*, 6 *g*, &c., parallel to *b f*. With *c b* set off from *e* to *f*; with 8, 7 set off from 1' to *g*; with 9, 6 set off from 2' to *h*; with 10, 5 set off from 3' to *i*; with 11, 4 set off from 4' to *m*; with 12, 3 set off from 5' to *n*, and so on, through *h g*, *h i*, &c., draw the curve.

In fig. 5, *a b* is the "cyma-reversa" moulding, *b d* the line of "raking," and *c d* the level return at top. In fig. 6, *a b* is the "cavetto" or hollow, *b d* the line of rake, *c d* the level return. In fig. 7, *a b* is the "ovolo," 6 6' the rake, and *a* 6' the

level return. In fig. 8, another "ovolo" is given, with a greater amount of rake than in fig. 7. The letters of reference, and the corresponding figures, should enable the pupil to delineate these various forms. In fig. 7, the method of obtaining the points is different from those adopted in the other figures. The raking lines parallel to 6 6′ start from the line *a* 7, in place of the divisions on the curve of the moulding, as in the other examples.

These examples now given are only single mouldings; in figs. 1 and 2 we give the method of delineating "raking pediments" with level returns at top. Carry up at the terminations of the mouldings, as A, A, A, perpendicular lines, as 7 1, 8 2, 9 3, 10 4, 11 5, 12 6. Let *c c* be the "rake" of the pediment, with 7 the point at which the level return at top commences. Erect a perpendicular, 7 1, and at right angles draw a line, 1 6; along this, from 1 set off divisions equal to those on the line, 1 6, at *a*. From the points on this line drop perpendiculars; these cutting the lines of the mouldings drawn parallel to *c c*, will give the termination of each moulding for the level return. Fig. 2 is a segmental pediment; a radial line is shown at *x x*. The line, *p p*, is the centre line of this figure; *v v* that of the pediment in fig. 1.

In the preparation of "working drawings," to save time, it is usual to lay down elevations and plans, &c., on the same paper, taking the various centre lines and projections for the plan from the elevation, or *vice versa*.

Thus, suppose the "section" in fig. 2, Plate VII., "Building Arts," to be drawn fully, as in fig. 1, Plate F, the various lines of the plans, as the ground plan, fig. 3, and the chamber plan, fig. 2, Plate VIII., "Building Arts," can be taken from this, as shown in figs. 2 and 3, Plate F, fig. 2 representing the back wall, with fire-places of the "ground plan," fig. 3, the back wall, with fire-places of the chamber plan, fig. 2, Plate XIV., "Building Arts." The corresponding letters of reference will fully explain the method of getting the various projections of figs. 2 and 3 in plan from the elevations of the various parts in section in fig. 1. The pupil should practise putting in "front elevation" from ground plan, and *vice versa*, of the various examples we have given in the plates illustrative of the article on the "Building Arts."

The diagrams in Plate C illustrate the method of obtaining the lines of stairs in elevation from the "plans." In fig. 1 we give the plan of a staircase with "winders." There are 18 "treads" in the staircase. Let *a b* be the height from one floor to another; draw the vertical line, and divide it into 18 equal parts; lines are drawn from these horizontally; the intersections of these with the vertical lines taken up from the plan, as shown, give the height of the "risers," and the width of the "treads."

In fig. 3 we give the plan of a dog-leg staircase, and in fig. 4 the elevation; the corresponding figures and the lines will amply explain, it is hoped, the method adopted. For detailed explanations of the various parts of stair-casing, see the article on the "Building Arts."

THE THEORY AND PRACTICE OF THE MANUFACTURE OF SUGAR.*

On several former occasions, the agreeable duty has devolved upon me of returning thanks to gentlemen, who, unconnected with this institution, have kindly, promptly, and efficiently assisted us in reference to the objects of these Friday evening meetings. On the present occasion, my grateful acknowledgments are especially called for. When I had made up my mind to invite your attention this evening to the interesting and important subject of the manufacture of sugar, it became necessary that I should minutely inform myself upon a variety of points connected with that manufacture, so as to be able to contrast its present with its former state. I therefore endeavoured to ascertain how far certain new processes have been successfully carried out, and to what extent a variety of novelties, both as regards machinery and manipulation, have been successfully adopted; I had, in short, to inquire how I could best qualify myself for coming before you this evening, so as to give an intelligible, but at the same time succinct account of the theory and practice of sugar refining; and for this purpose I found it necessary to gather information from several distinct sources. Suffice it to say, that on all hands it was most liberally afforded; so that, if to-night I fail in my object, the fault will be entirely my own, and not from want of attention or courtesy on the part of others. There are three parties to whom I am especially indebted. In the first place to Messrs. Shears, through whose exertions and liberality I am enabled to place before you a complete working model of the vacuum pan and all its appendages. I am also under considerable obligations to Dr. Scoffern, the inventor of a new and important process, by which the purification of raw sugar is accelerated, and the produce of crystallizable sugar, as I am informed, increased. To the kindness of Messrs. Thwaites, of Cork, I am indebted for the materials upon which I shall operate, for samples of raw and refined sugar, for the saccharine solutions or *liquors*, as they are technically called, which I shall employ, and for several other aids; and, lastly, my thanks are due to Messrs. Goodhart, Son, and Patrick, who, as well as Messrs. Thwaites, have adopted Dr. Scoffern's process, and who have been good enough to give me access to their sugar-house, and all other facilities for inquiring into the practical details of the refinery.

Sugar is a very interesting substance, not only on account of its chemical habitudes and peculiarities, but from the rank which it occupies amongst dietetic products, and its high and increasing commercial importance. Into the details of the chemistry of sugar, it is not my wish at present to enter; but there are some of its properties to which I must necessarily advert, in order to render myself intelligible in reference to its manufacture.

In the first place, I may observe that there are numerous varieties of sugar, two of which only require here to be noticed, namely, *cane sugar* and *grape sugar*.

Cane sugar, as its name imports, was once exclusively obtained from the sugar cane *(arundo saccharifera)*; but there are many other plants in which the same kind of sugar is found, and from several of them it has been economically extracted. It is found in the juice of several of the palm tribe, more especially in the *date palm (phœnix dactylifera)*; in the sap of the *cocoa-nut tree*; in the expressed juice of the *beet-root (beta vulgaris)*; in the sap of certain species of *maple (acer saccharinum)*; and in that of the so-called Indian wheat, or maize *(zea mays)*.

Grape sugar abounds in the fruit of the vine, and is often seen incrusting old raisins; indeed, most fruits derive their sweetness from it; it is familiar to us upon dried figs, plums, &c.; it is abundant in honey; and starch, and even woody fibre, or lignin, may be artificially converted into it. It is found in *malt*; and a curious case of its production takes place in the brewer's mash-tun, where a peculiar principle, called *diastase*, tends to its formation, by acting upon the mucilaginous and starchy ingredients of the grain.

The ultimate elements of cane and of grape sugar will be found to be correctly stated in the following table:—

CANE SUGAR.

	Atoms.	Equivalents.	Per Cent.
Carbon,	12	72	42·1
Hydrogen,	11	11	6·4
Oxygen,	11	88	51·5
Total,	1	171	100·0

GRAPE SUGAR.

	Atoms.	Equivalents.	Per Cent.
Carbon,	12	72	36·4
Hydrogen,	14	14	7·1
Oxygen,	14	112	56·5
Total,	1	198	100·0

From which it appears that they are both constituted of carbon, and of hydrogen and oxygen, the latter elements being in the same relative proportions as they exist in water; so that

* Delivered before the Royal Institution. By William Thomas Brande, Esq., F.R.S., of Her Majesty's Mint, and Professor in the Royal Institution.

chemists are sometimes in the habit of speaking of both these sugars as compounds of carbon and water; not thereby implying that they are actual hydrates of carbon, but that the atomic relation of the hydrogen and oxygen in sugar is one and one, or that they are to each other by weight in the proportion of one to eight. In this way, we say that cane sugar is a compound of twelve atoms of carbon and eleven atoms of water; and grape sugar, of twelve atoms of carbon and fourteen of water; whence we should infer that two atoms of (the elements of) water must be combined with an atom of cane sugar to convert it into grape sugar; and that two atoms of (the elements of) water must be subtracted from grape sugar in order to convert it into cane sugar. In practice, the conversion of cane sugar into grape sugar is easily effected; but the converse change, namely, that of grape into cane sugar, has not yet been accomplished.

The distinctive characters of cane and grape sugar are well marked, and important; cane sugar, as seen in the common candy of the shops, is eminently crystallizable, being easily obtained in the form of large and well-defined six-sided prisms; whereas grape sugar concretes into small fibrous groups of hemispherical tubercles, composed of an assemblage of acicular crystals. The sweetening powers of cane sugar are also greatly superior to those of grape sugar, so much so, that in giving sweetness to any liquor, tea, for instance, two parts of cane sugar go as far as five of grape sugar. Another more important chemical distinction between these two kinds of sugar is founded upon their respective actions upon an alkaline solution of tartrate of copper, made by dissolving the latter salt in solution of carbonate of soda; we thus obtain a deep blue liquor, which is frequently known under the name of *sugar test.* When cane sugar is added to this blue liquor, it produces no immediate change of colour; but after a time a blue precipitate falls, especially on heating the mixture, which appears to be a compound of sugar and oxide of copper. When, on the other hand, grape sugar is used, the deep blue tint of the original liquor is almost immediately impaired, and it passes into a grass-green, which, on the application of heat, changes to brown, and a copious brown precipitate of sub-oxide of copper, and even portions of metallic copper, are subsequently thrown down.

We must now advert to the transmutation of cane into grape sugar, which I have already incidentally mentioned: this may be effected in various ways, amongst which, one of the readiest is the action of ferments; and indeed in all cases of the fermentation of saccharine liquors containing cane sugar, the first step of the process consists in its passage into grape sugar, and that grape sugar is subsequently split into carbonic acid and alcohol.

But there is another and less complicated case of this change of the one sugar into the other, which has more immediate bearing upon our present subject, and which we must, therefore, more particularly examine; for it is evident, that all operations by which this conversion is effected, or by which, in other words, crystallizable cane sugar is converted into uncrystallizable and unprofitable grape sugar, are eminently injurious to the sugar manufacturer, whether we consider them as affecting the preparation of raw sugar, or as influencing the results of the refiner. The case to which I allude is the continuous action of *heat* upon sirup. If I boil a dilute and colourless sirup—that is, an aqueous solution of cane sugar—for a few hours, it gradually acquires a brown tint and a burnt odour, and on continuing the boiling, and occasionally adding water to make up the loss by evaporation, these changes go on increasing; and it is ultimately found, that by this simple operation a considerable part of the original cane sugar has been modified into grape sugar; that crystallizable sugar can no longer be obtained from the sirup; and that its reaction upon the *copper test* is that of grape sugar. Thus, then, the deterioration of the original sirup by the mere influence of protracted boiling, for which, under atmospheric pressure, a higher temperature than that of boiling water is required, is made manifest. But if a little *acid* or *alkali* be added to the cane sugar sirup, the changes thus effected by heat are more rapid and destructive. I have here weak sirups which have been boiled for a few hours with the addition of a few drops of muriatic, nitric, and sulphuric acids, and in all of them grape sugar has been formed, and other and more complicated changes have to a greater or less extent ensued. That which has been acidulated by muriatic acid is brown and uncrystallizable; that with nitric acid, brown, viscid, and more evidently altered; that with sulphuric acid, limpid and uncrystallizable; and in all these cases, if the heat be continued, further decompositions ensue, and a complicated variety of new products, generally of an acid character, are the results. Some of these new products form dark-brown insoluble compounds with the majority of basic bodies, and may be termed *melassic* or *melassinic acids;* others are of the character of ulmic acid, humic acid, and so on. Even the vegetable acids effect, in some cases, analogous changes; and the greater number of them, amongst which are acetic, tartaric, and citric acids, prevent the crystallization of cane sugar, and, when aided by heat, produce in it more decided chemical changes.

The alkalies, such as potassa and soda, produce some extraordinary changes upon sugar; so also does lime-water; thus, if sugar be dissolved in lime-water, and the liquor boiled, it acquires a brown tint, and when set aside deposits minute crystals of carbonate of lime, together with a precipitate apparently composed of lime in combination with some other acid products generated by the joint action of heat and lime upon the sugar. With baryta, analogous changes ensue to a greater extent.

From this short and very imperfect statement of the action of heat, acids, and alkalies upon crystallizable or cane sugar, it is manifest that they exert upon it a destructive agency, and that in all operations connected with the original production of sugar from the juice of the plant, and in all subsequent processes in which raw sugar is refined, a high heat, protracted boiling, and the presence of acid and of alkaline or basic bodies, should be avoided, inasmuch as they, not only collectively, but even individually, tend either to convert cane into grape sugar, or to effect more destructive changes.

My time will not allow of my saying anything in detail upon the subject of the original production of sugar, as conducted in the West and East Indies, and elsewhere; so that I must limit myself to those operations which are carried on in the sugar refineries of this country, in which raw or muscovado sugars of various kinds, and from various sources, are operated upon, and where the object is to obtain from them the largest possible produce of pure, or, as we usually call it, of *loaf sugar*, in the shortest possible time, and at the least expense.

In the old process of sugar refining, a copper boiler was charged with lime-water, mixed with a certain proportion of bullock's blood; to this mixture the sugar was added: it was suffered to stand a night to dissolve, and early in the morning a fire was lighted under the pan or boiler; when the liquor boiled, the albumen of the blood coagulated, and entangling the mechanical impurities of the sugar, formed a scum, which was constantly removed. The simmering was then continued, till a sample, taken out in a spoon, appeared transparent; after which it was further rapidly boiled down, till of such consistence as to draw into threads between the finger and thumb, some practical skill being required to ascertain the exact point at which the boiling should be stopped. At this point the fire was damped, and the sirup transferred to a vessel called a "cooler," where it was agitated with wooden oars till it granulated. In this granular state it was transferred to the moulds, to be treated as I shall afterwards mention, when I shall advert to another part of the process, relating to the decoloration of the sugar by animal charcoal.

Now, having already mentioned the injurious changes which sirup suffers by heat alone, to say nothing at present of the lime, blood, and other matters, it is manifest that a loss must have been sustained from that cause only; and this leads me to ask your attention to the importance of the *vacuum pan*, that is, of boiling the sirup under diminished atmospheric pressure, and, consequently, at a much lower temperature than that required in the open air. And inasmuch as the injury sustained by the sugar is directly proportional to the temperature to which it is raised, and to the time at which that high temperature is

maintained, the advantage of greatly diminishing the heat, and at the same time accelerating the evaporation, will at once be obvious.

The invention of the vacuum pan is due to the Hon. Edward Howard, who patented it in the year 1819. It consists of two hemispheres somewhat flattened and bolted together by flanges; it is made of copper, and often of very large dimensions. The lower hemisphere is imbedded in a steam jacket, and has besides a coil of copper steam-pipe, which lines its interior, so therefore as to present a great heating surface, and rapidly raise the temperature of the liquor let into it. Attached to the pan, at its upper part, is a pipe of communication with a cylindrical vessel, resembling the condensing apparatus of a low-pressure steam engine, into which a subdivided stream of cold water is continually passing, so as to condense the vapour arising from, and constantly pumped out of, the pan by means of an annexed air-pump, which, as in the steam engine, keeps up a vacuum in the pan, and removes the water of condensation. The proper quantity of saccharine solution is let into the pan by an adjoining measuring vessel, which empties itself into the vacuum pan by the air's pressure. There are also several other accessories to the vacuum pan, namely, a thermometer, a barometric gauge, and a *proof-stick*, which is a clever contrivance, enabling the operator to take samples of the liquor in the pan without admitting air.

At the lowest part of the under hemisphere of the vacuum pan is a pipe, and valve or cock, through which the sugar solution, when sufficiently boiled, is allowed to escape into the heater.

Under these circumstances, then, the purified and decolorized sirup is reduced by evaporation to such consistency that it begins to granulate; that is, that a sample taken out of the vacuum pan by means of the *proof-stick*, and placed between the finger and thumb, feels somewhat gritty, in consequence of the formation of small crystalline grains. When this is the case, air is allowed to enter the vacuum pan, and its contents are quickly drawn off into a vessel placed underneath for their reception (*the heater*), which is heated by a steam jacket. Here the granulating sirup is agitated till it has acquired the peculiar condition or consistency which fits it for pouring into *moulds*, which, as is well known, are conical vessels, made of earthenware, or of glazed iron, or of copper, with a small aperture at their apex. These vessels are placed with the bases upwards, and the hole at the apex being stopped, they are filled with the granular saccharine magma, which now concretes or *sets*, and may be represented as a mass of granularly-crystalline sugar, the pores of which are filled with more or less pure sirup. Considerable practical tact is required to ascertain exactly the fit condition of the semi-fluid saccharine mass for introduction into the moulds; if too liquid, the loaf cannot properly solidify; if too concrete, it becomes what is technically called *sirup-bound*, that is, it does not allow the sirup to trickle from it when the stoppers are removed from the apices of the moulds—an operation which is conducted in a warm atmosphere, and upon the perfection of which the character and appearance of the loaf mainly depend. It is in these conical moulds that the curious operations of *claying* and *liquoring* are performed; that is, that sirup is allowed to filter through the loaf, by placing a mixture of sugar and water upon its base, the watery parts of which dissolve the residuary soluble matters as they pass, and dribble out at the apex into a vessel placed to receive them. In this way the colour of the loaf, and its texture, are both improved; the former, by the removal of certain soluble matters; the latter, by the deposition of sugar from the percolating sirup. When these operations have been so far perfected that the loaves admit of removal from their conical moulds, the bases and apices are trimmed, and they are completed by drying at a high temperature.

I must now revert to certain improved methods of treating the original solution of raw sugar, and which supersedes the noxious operations of heating with lime-water and blood, and subsequent skimming and boiling. Although by these processes much mischief was done by the protracted application of a high degree of heat, and by the chemical agencies of the lime and blood, the former decomposing and modifying part of the sugar, and the latter giving it colour and a disagreeable odour, they, nevertheless, tended to abstract certain matters, which, had they remained in the liquor, would have seriously interfered with the subsequent crystallization or granulation of the product. It is to this step of the sugar manufacture that I must now direct your more especial attention, and principally in reference to Dr. Schoffern's process, which I have already hinted at, and the principles and practice of which I shall now endeavour to illustrate.

The sample of raw sugar which I have purposely selected for these operations, is, as you see, of the very roughest character; it is called "Khoar sugar," and is produced in the East Indies by evaporating the sap of certain species of palms, more especially the *date palm*. It is so black, coarse, and impure, as I believe to have been generally considered unfit for the purposes of the refiner; yet, by the improved processes which are before us, and by the application of scientific principles to the practical details of the manufacture, it has been made to yield the beautifully white, crystalline, and perfect loaf of sugar which lies beside it.

There are two points which require your especial notice, and which must always be borne in mind in considering the operations now under discussion: namely, first, the mere removal of colour; and, secondly, the removal of other things besides colouring matter, which are present in the raw sugar, and which are fatal to its crystallizability; these are, it is true, often closely allied to, and even themselves sources of, the dark colour of raw sugar; but it is very possible to deprive brown sirups of their colour, and yet leave a product unsusceptible of crystallization, or at least incapable of that peculiar *granular concretion* which must be attained in order to form *loaf sugar*.

Now it is obvious, that if we possess an agent capable of at once bleaching the raw product, and at the same time abstracting the complicated extractive and acid matters which are fatal to granular purity, we have attained a most important desideratum in this art; and such seems to me to be, to a great extent, the case with respect to the agents, for the first time suggested by Dr. Schoffern; and it is clear that, if I am correct upon this point, three important advantages must hence ensue: namely, 1st. Raw sugars of so coarse a description as to be unavailable in the ordinary routine of procedure, may be employed as sources of loaf sugar. 2nd. By doing away with the use of lime and blood, that portion of the sugar which those agents either deteriorated or destroyed will be saved. 3rd. The whole process of purification will be completed in a short time. How far these ends are actually attainable in practice, and how far the results which you witness at this table are legitimately transferable to the refining of sugar, upon the gigantic scale on which it is conducted in our sugar-houses, is a question which I must leave to others. I wish to confine myself here to the chemistry of the subject, and to inferences fairly deducible from the facts I shall place before you.

Now, as respects the mere *decoloration* of the sugar, there are many substances which from time to time have been suggested as more or less efficacious; but none of them can at all compete with certain modifications of *charcoal*, more especially with what is called *animal charcoal*; and that variety of it derived from the destructive distillation of bone, horn, and matters of that kind, and which is usually mixed with a large proportion of phosphate of lime, is generally in practical use for this purpose. By its means, a brown sirup may be, under proper management, rendered colourless, and the resulting sugar of almost dazzling whiteness; it is, therefore, eminently useful, where such perfect whiteness is desirable; and is also employed, to a less extent, where less absolute deprivation of colour is required. But, to say nothing of the expenses incurred by the use of this material, and the loss of time attending the processes of filtration, those substances which mainly interfere with the crystallization of the sugar can never be abstracted by charcoal; it is upon these that the lime appears chiefly to operate in the old process; and it is for the removal of these, that certain *preparations of lead* have long ago been suggested; for if a solution of acetate of lead be added to a brown sirup, it not only carries down the principal part of the colouring matter, but also those other compounds which have been adverted to, as inimical, not only to

the whiteness, but the granulation of the sugar. But then came the difficulty of abstracting the whole of the lead, so as to insure the entire freedom of the filtered sirup from *every trace* of that metal; and to do this, without in any way injuring the sugar. This important problem remained practically unsolved, until Dr. Schoffern succeeded in discovering a very simple and effective means of getting over the difficulty, by the employment of *sulphurous acid*, which combines with the lead, to form a perfectly insoluble compound—namely, *sulphite of lead;* while it has no destructive agency upon the sugar itself, and at the same time admits, when used in excess (and such excess is necessary to insure the complete effect), of being readily expelled by heat alone.

Sulphurous acid is a gaseous body. It is formed by burning sulphur in the air; or better, by burning it in oxygen gas, when it produces a magnificent blue flame. In this way the oxygen sustains no change of volume, but, combining with its own weight of sulphur, becomes converted into sulphurous acid, which is a compound of one atom of sulphur with two of oxygen, as shown in this table:—

	Atoms.	Equivalents.	Per cent.
Sulphur,	1	16	50
Oxygen,	2	16	50
Sulphurous acid,	1	32	100

Sulphurous acid is very soluble in water and in sirup, which immediately absorb it in large quantities, but from which it may be entirely expelled by the application of heat. When sulphurous acid gas is passed into a solution of acetate or subacetate of lead (compounds of acetic acid and oxide of lead), it combines with and carries down the whole of the oxide of lead, forming with it a dense white insoluble precipitate; and the acetic acid is entirely displaced, and remains in the supernatant liquid, which, if the operation has been properly conducted, is now entirely free from all trace of lead. In sulphuretted hydrogen, we fortunately possess a most delicate and infallible test of the presence of lead, with which it forms a black insoluble compound. So that if I add a solution of sulphuretted hydrogen to any liquor containing even the minutest trace of lead, it is indicated by a black precipitate; or if the lead be in such imponderable quantity as not to be thus thrown down, its presence is, nevertheless, detected by the production of a dark cloud.

I will now show you the application of these chemical facts to the purification of sugar. I have here a solution of very impure raw sugar. I add to it a solution of subacetate of lead. I get a copious dirty-brown precipitate, which I separate by filtration. The filtered liquor is pale and transparent, but is immediately blackened by the addition of the *lead test* (sulphuretted hydrogen), showing, therefore, that although a part of the lead has gone down in combination with various matters in the raw sugar, forming the precipitate which is left upon the filter, another part has been retained in the clear liquor; it is, in fact, dissolved in the bright sirup. I shall now pass a current of sulphurous acid through the filtered sirup, and you observe that it presently becomes turbid, in consequence of the formation of an insoluble sulphite of lead. And now, if I again filter, I obtain a perfectly clear and bright sirup, from which I expel the redundant sulphurous acid by the application of a moderate heat; and I now find that, on the addition of the solution of sulphuretted hydrogen, there is not the slightest discoloration. I have, therefore, the most decisive evidence that the *whole of the lead* has thus been effectually removed. The purified sugar is left intact, and on evaporation it granulates. Here, then, you have an opportunity of seeing, step by step, in small tubes and glasses, all the separate details of Dr. Schoffern's process, as it is conducted upon the large scale. One only point I have omitted in reference to these operations—not wishing to draw your attention from the main points—and it is this, in decomposing the acetate of lead, a small quantity of acetic acid will, of course, be set free; and this, if allowed to remain in the sugar, might possibly injuriously interfere with its subsequent crystallization. To remove this free acid, therefore, a small quantity of chalk is added to the liquor, so as to form acetate of lime. a product in no way injurious, and which, in the subsequent operations to which the sugar-loaves are subjected, is washed out.

The attraction of the oxide of lead for the colouring matters of raw sugars is by no means an unimportant fact, inasmuch as it in so far does the duty of charcoal; and, accordingly, where extreme whiteness is not called for, it supersedes the use of charcoal; and where that whiteness is required, less charcoal will be requisite.

Where the process which I have now endeavoured to illustrate and explain, both as regards theory and practice, is carried on upon the large scale, its various steps are nearly as I have described them. They are briefly as follows:—The raw sugar is dissolved in water, heated by steam, in a vessel technically called the *blow-up*, and here the proper quantity of subacetate of lead is added. The contents of the blow-up vessel having been well agitated and mixed, are then transferred to proper filters, to separate the precipitated matters, and the clear filtered liquor is subjected to a stream of sulphurous-acid gas. When it has been duly *gassed*, it is again filtered, either through charcoal, or merely through bag-filters, as may be required; and the filtered liquor is tested by sulphuretted hydrogen, and counter-tested, so as to show that the whole of the lead has been abstracted. A little chalk is then added, and the clear sirup boiled down to proof in the vacuum pan. It is then run off into the heater, granulated, and transferred to the moulds, when the process is completed by claying and liquoring, as above described.

There is only one other point to which, before I conclude, I should desire to call your attention—I mean, to the nature of the precipitate, which is produced on first adding the subacetate of lead to the dark solution of the raw sugar. It is of a dirty-brown colour, and when dried, pulverulent, and nearly tasteless. It appears to consist of brown extractive matter, and certain coloured substances of an acid character, in combination with oxide of lead. It is insoluble in water, but soluble to a small extent in alcohol; and if it be diffused through alcohol, and then subjected to the action of sulphurous-acid gas, a white sulphite of lead is formed, and the matters previously in combination with the oxide of lead are transferred to the alcohol, forming with it a dark-brown tincture. When this alcoholic solution is filtered and evaporated, it leaves a dark-brown residue, representing the colouring matters, melassic acid, &c., with which the crystalline sugar was combined and contaminated in the original raw sample.

INVENTIONS TO INCREASE THE SAFETY OF STEAM BOILERS.

The recent boiler explosions have set our inventors on the *qui vive*, and we hail with pleasure the many evidences of ingenuity directed towards this special object, trusting that they will lead to the development of means by which the safety of boilers may be made a matter of practical certainty. Self-acting contrivances are most to be desired, if they are such as can be relied on with undeniable security.

Several designs having this desirable end in view, have lately been patented. We now proceed to describe and illustrate three of them, which appear highly commendable from their simplicity.

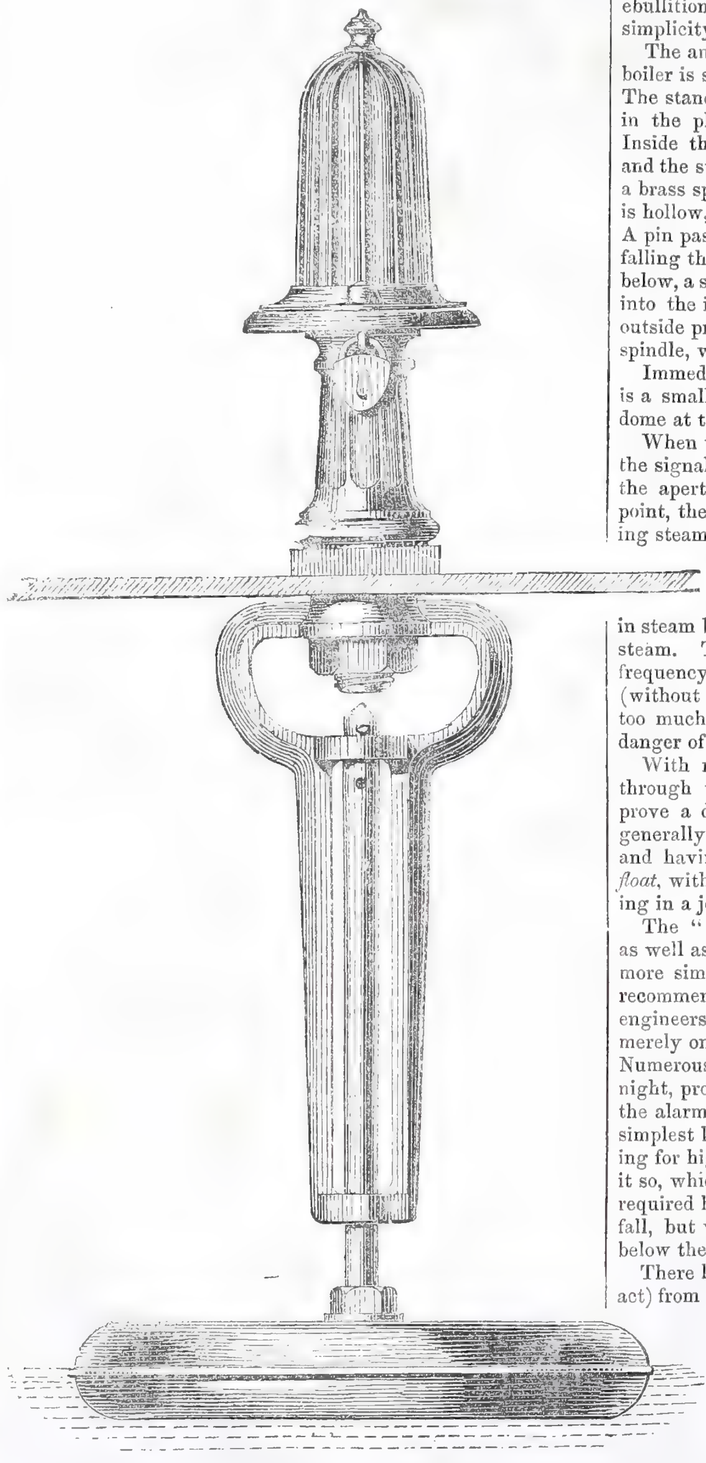
HALEY'S SAFETY SIGNAL FOR STEAM BOILERS.

By this very neat and simple adaptation of a direct-acting float to a steam-whistle, notice is given when the water-level in the boiler has sunk below the proper point.

Mr. Fairbairn, and many other unquestionable authorities, are of opinion that boiler explosions frequently arise from a deficiency of water; and that against accidents arising from this special cause, the best safety-valves are no adequate security. The sudden development of vapour of enormous elasticity, produced by water coming in contact with overheated iron surfaces, requires openings for its instant escape of greater size than can practically be used; and therefore the only proper security against such development must be of a preventive, rather than of an alleviative character.

Next to a certain means of maintaining the proper water-level, by self-feeding apparatus of a kind to be relied on (all the existing means being liable to occasional derangement), is an infallible and unmistakeable announcement, by which the boiler itself shall give notice when the water has, by accident

Fig. 1.



or neglect, gone below that proper level; and even in conjunction with more certain means of self-supply, a precautionary mode of giving alarm, in case of its failure, is worthy of adoption.

The importance of adopting such an alarm as shall not be liable to derangement, cannot be over-estimated; the absence of working parts is, therefore, a most valuable feature in the signal now before us. There is only one moveable piece, which being a mere upright brass spindle, having considerable play in a guide bar, through which it passes, and being kept in constant agitation, like Nasmyth's safety-valve, by the ebullition of the water, confers on this signal the property of simplicity in an eminent degree.

The annexed engraving, in which a part of the top of the boiler is shown in section, conveys a clear idea of this signal. The stand outside the boiler has a stem passing through a hole in the plate, screwed at the end, and provided with a nut. Inside the boiler, it passes through the guide, and secures it and the stand at the same time. A copper float is screwed upon a brass spindle, working loosely through the guide, and which is hollow, except at the top, and is formed into a conical shape. A pin passes through this spindle near the top to prevent its falling through the guide when the boiler is empty, and a little below, a small aperture admits steam through the hollow spindle into the interior of the float, by which means the inside and outside pressure are equalized; and being near the top of the spindle, water cannot enter the float.

Immediately over the cone, through the stem of the stand, is a small aperture leading to a whistle locked up within the dome at the top.

When the water is any distance above low-water mark, or the signal point, the float is lifted, and the cone presses against the aperture and closes it. When it falls below the warning point, the float falls with it, and the aperture is opened, allowing steam to pass through it to the whistle.

There have been, from time to time, various inventions, some patented or registered, for the purpose of giving warning of a deficiency of water in steam boilers, and, in some cases, for high water and surplus steam. The latter have met with objections on account of the frequency of the alarm, and the impossibility of ascertaining (without a visit to the boiler every time), whether it denotes too much water, a surplus of steam, or the approaching *real* danger of want of water.

With regard to the signal for surplus steam, the valve through which indication has to be given is more likely to prove a defaulter than the simple safety valves now being generally adopted, the former being a conical valve, weighted, and having to be raised by the precarious force of a *balanced float*, with the attendant evil of a lever inside the boiler, working in a joint, &c.

The "safety signal" is registered to give warning for *high* as well as low water, and although the apparatus to effect it is more simple than any yet offered, its suppression was at once recommended by Messrs. Fairbairn, Galloway, and other eminent engineers; high water not being a question of danger, but merely one of economy, and on which men differ in opinion. Numerous instances are found where the boiler is filled at night, providing for evaporation until morning, in which case the alarm would do much mischief. By a contrivance of the simplest kind (since discovered), it may be made to give warning for high water also, by those who are determined to have it so, which is effected by drilling a hole in the spindle at any required height: the water entering the float will cause it to fall, but will regain its usual position when the water sinks below the aperture.

There have been, and are, water alarms which act (or should act) from the float wire. Any one, the least conversant in such matters, knows how liable this is to fasten, either from the stuffing being a little too tight, or the rod wearing less at the part where usually acting. The slight power of the balance float is quite insufficient to overcome the additional friction when the rod is drawn from the worn part; the apparatus is, consequently, worse than useless; in addition to which evil, some have to turn a steam cock, which alone is a sufficient objection.

The superiority claimed for the safety signal over any hitherto offered is, first, that there is not a fitted working part which

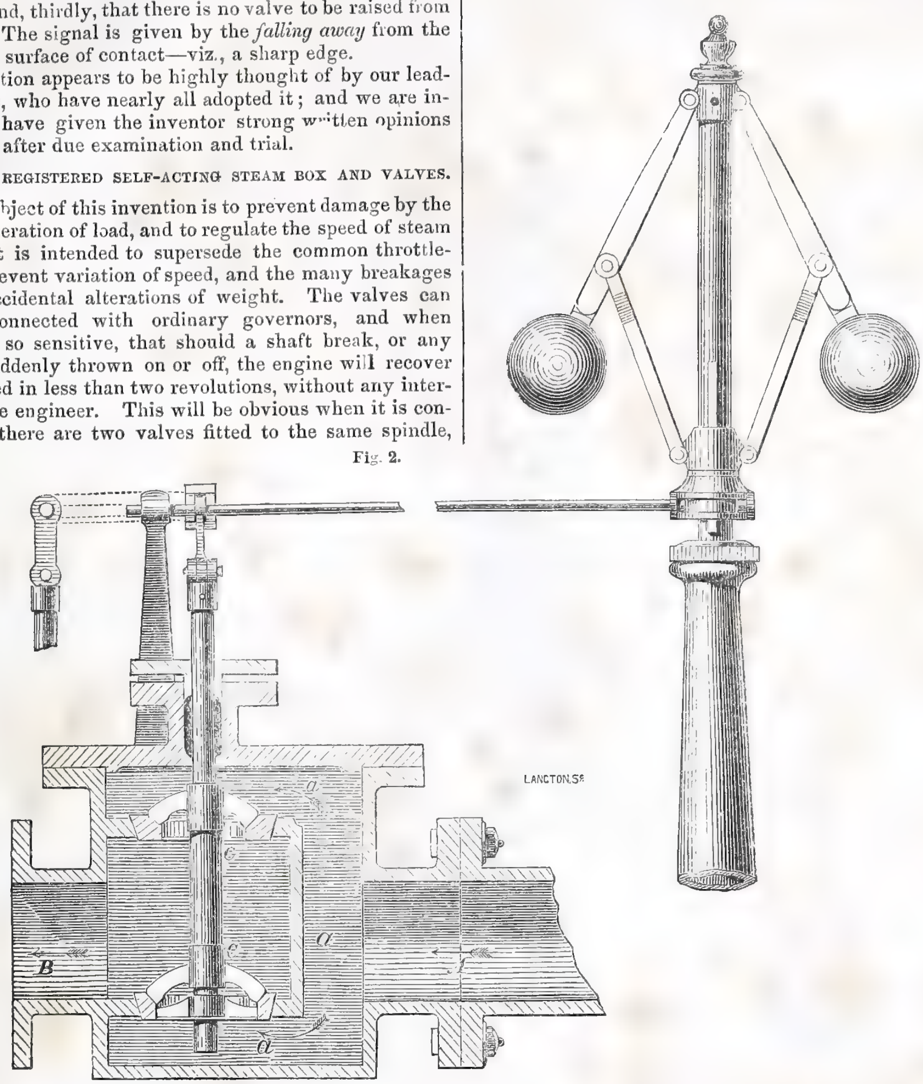
can possibly fasten or become deranged; secondly, that the action of the float is direct, its force defined, and not subject to change; and, thirdly, that there is no valve to be raised from its seating. The signal is given by the *falling away* from the least possible surface of contact—viz., a sharp edge.

This invention appears to be highly thought of by our leading engineers, who have nearly all adopted it; and we are informed some have given the inventor strong written opinions in its favour, after due examination and trial.

WHITEHEAD'S REGISTERED SELF-ACTING STEAM BOX AND VALVES.

The main object of this invention is to prevent damage by the accidental alteration of load, and to regulate the speed of steam engines.* It is intended to supersede the common throttle-valve, and prevent variation of speed, and the many breakages arising by accidental alterations of weight. The valves can readily be connected with ordinary governors, and when attached are so sensitive, that should a shaft break, or any weight be suddenly thrown on or off, the engine will recover its usual speed in less than two revolutions, without any interference by the engineer. This will be obvious when it is considered that there are two valves fitted to the same spindle, and, consequently, that each of them need be opened to only one-half the extent, as if there were one valve. The result is,

Fig. 2.



a throttle-valve of extreme sensibility, half an inch being the utmost amount of play allowed to the spindle between wide open and quite shut; therefore, a very slight change in the position of the governor balls produces considerable change in the amount of opening afforded by the valves.

The governor is connected with the valve spindle by a fork in the usual manner, which, by means of a crank lever, gives a slight motion on its axis to a bar, provided at the other end with another crank lever connected with the valve spindle. It may be attached to all ordinary governors.

In the case of two fifty-horse power engines, coupled together in Sir E. Armitage's mill, at Pendleton, the result of a trial by throwing off the *whole* weight, was a recovery of the usual speed in $1\frac{3}{4}$ revolutions. The load on these two engines consisted of 20,000 throstle spindles, 13,000 mule spindles, and 250 power-looms, with all the necessary apparatus for working the mill.

An apparatus so delicate and instantaneous in its regulating performance as this, would seem to render quite unnecessary any such contrivance as the compensating fly-wheel, which has been lately proposed. Protection is claimed for the shape of the valve-boxes, and for the spindle and valves.

* Manufactured by Mr. Thomas Gadd, Engineer, Lower Mosley Street, Manchester

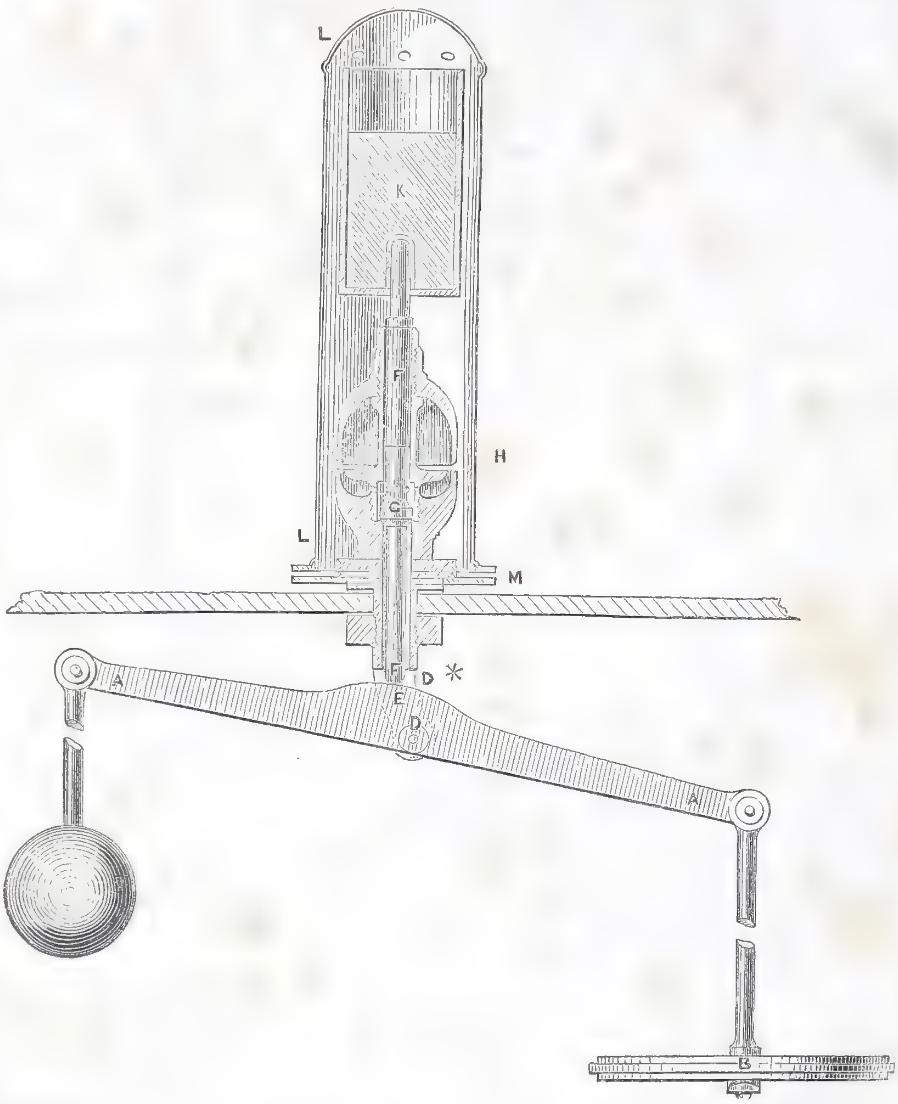
MELLOR'S COMBINED SAFETY VALVE AND WATER-LEVER INDICATOR.

This is a registered design for indicating the height of water in boilers, and the pressure of steam. It differs from the last described invention in the double purpose which it aims at, as well as in the details of its arrangement; but in both, a float is the essential part on which the performance of those details depends.

The design consists in a novel configuration of parts, applicable to steam boilers, for giving notice when the water in the boiler has sunk below its proper level, or the steam has risen beyond the intended pressure. The accompanying engraving represents the apparatus in vertical section. The lever placed within the boiler is shown at A A, from one end of which is suspended the ordinary float, B, and from the other, a counterbalance weight, C. The centre pin, D, upon which the lever turns, is carried by a bracket, D.* Upon the upper side of the lever, A, is a raised part, E, and above this, but set at one side of the centre pin, D, is a vertical spindle, F, which carries an ordinary valve, G, having its seat within a whistle, H. The spindle, F, extends upwards from the valve, and is there weighted, as shown in the engraving. According to the position of the lever, as represented, the water has sunk so as just to bring the projecting part, E, thereof in contact with the

bottom of the spindle, F. By continuing the motion in this direction, the valve will be lifted, and the steam will escape into and through the whistle, so as to give the necessary alarm. This will continue so long as the water is below its proper level; but owing to the peculiar position of the centre, D, with reference to the spindle, F, no such motion will take place upon the rising of the float after it has gained its proper height. Should the steam attain an undue pressure the weighted spindle will be raised, and the opening of the valve will allow an escape to take place through the whistle, so as to afford the

Fig. 3.



required alarm. The weight consists of a cast-iron cup, K, which may be filled with shot to any desired pressure.

From this it will be seen, that as the water becomes low, the float follows, pulling down one end of the beam, which raises the spindle of the valve, and gives the alarm; also, when the pressure of steam becomes greater than is required, the valve spindle, with the weight upon it, is raised, and gives the same notice.

THE GLASS MANUFACTURE.

CHAPTER II.

THE MANUFACTURE OF HORTICULTURAL OR GERMAN SHEET GLASS.

In our former chapter on this subject, a general outline was given of the processes followed in the manufacture of the different kinds of glass; and it now only remains to select a particular branch of the manufacture, with a view to illustrate the operations more in detail. The making of Horticultural or German sheet glass, being of comparatively recent introduction into England, and combining in itself a very complete view of the principles and leading processes of the art, appears to be well adapted for this purpose, and a short account of it may be interesting to the non-professional reader.

The common mode of procedure in the production of blown sheet glass, by what is technically termed "flashing," is so generally understood that we need not refer to it further than to state that the chief innovation in the process under consideration is the substitution of a method of *cutting open* the blown glass instead of the system of "flashing."

The leading features of the improvement may be said to have originated in this country, having been introduced in what is termed the "blown plate" manufacture; that is, glass first blown and afterwards ground and polished in a manner

similar to that at present pursued in the making of "plate glass" *par excellence*. After its introduction here, where it did not make much progress, it passed to the continent, and what was left undone by ourselves was energetically prosecuted by our neighbours, the Belgians.

In 1832, the process having attracted the attention of the English manufacturers, it was re-imported here and first commenced in Birmingham by twelve Belgians, assisted by a number of English workmen.

As usual in all new branches, this process advanced slowly for some time, but gradually overcoming the various obstacles opposed to it, it has latterly become of itself a most important manufacture.

As before remarked, the main distinction between German sheet and Plate glass is, that the former is blown and the latter cast, and whereas German sheet is blown into long "cylinders" or "muffs," which being cut on one side, are opened into flat rectangular plates, Crown glass is blown into globes, which whilst in a soft state are opened and as it were, turned inside out, by being rapidly spun round in a manner similar to that of twirling a mop, the centrifugal force thus acquired spreading or "flashing" the glass into circular plates or "tables," each having a lump of glass in the centre. To this lump it is that the tool is attached, and afterwards forms the well-known "bullion" or "bulls eyes," so frequently seen in stable and other inferior windows.

The name *German* sufficiently implies the locality whence this mode of manufacture sprung, but most of the "blowers" or head workmen are Belgians, who receive wages varying from four to seven pounds sterling per week, exclusive of "plus" or overwork, and in addition to a furnished house, rent free, coals, and a free passage from and to the continent at the beginning and expiration of their term of contract. About 2000 persons find employment in this peculiar branch, all of whom are more or less assisted by a host of boys, whose services though trifling are necessary to the various mechanics upon whom they attend.

There is nothing peculiar about the furnaces, and the crucibles or "pots" in which the glass or "metal" is melted, they are in every respect the same as those employed for crown or plate glass; nor is there any very essential difference between the "frit" or composition of raw material for crown and sheet glass, excepting that the materials for the sheet are selected with a greater regard to purity. The mixture of sand, soda, and lime, having been made in accordance with the peculiar views of the manufacturer, the "frit" is shovelled cold into the heated "pots," in which it is subjected to an intense heat from 12 to 20 hours, when it becomes quite fluid and clear. The furnace is now allowed to cool until the melted glass becomes of the consistence of common honey, when the impurities on the surface are removed by skimming, and an assistant plunges an iron pipe of about 5 or 6 feet long, and 10 lb. weight, into the semi-fluid glass, and by turning it round "gathers" a portion of glass on the end of his tube; after this has become stiff by cooling, the process is repeated until a sufficient quantity is thus obtained, in the shape of an irregular sphere. The pipe is now cooled over a tub of water, and is transferred to the "blower," who, keeping it constantly revolving, lays the glass in the "block," which is a sort of wooden bowl partly filled with water. The peculiar shape of the cavity, and the motion given to the glass by the workman, cause it to assume a shape which he knows by experience to be best adapted to his purpose. It will no doubt seem strange to the reader that hot *glass* should be plunged into cold water, and this rarely fails to strike a stranger with astonishment, as knowing, by somewhat costly experience, how soon hot glass is cracked by cold water, he cannot understand why it does not crack now, and frequently thinks there is some secret or craft mystery in the affair, often asking, "but, is it *really* water?" That the glass does not crack most probably arises from its non-conducting properties, as well as from its being so very hot and soft that it does not lose sufficient heat, during the time it is immersed, to become brittle; the spheroidal state which water assumes when in contact with some bodies at very elevated temperatures, also tends to prevent the glass losing heat so rapidly as might be imagined, and the water, in fact, acts only as a lubricating substance between the soft glass and the wood thus effectually preserving the surface of the former from being injured by the half-charred bowl.

Fig. 1.

Fig. 2.

The mass is now of the shape, fig. 1, and being blown into and slightly drawn out, by allowing it to hang down from the pipe, it assumes the shape of fig. 2, being a thick pipe a little conical, terminated at the larger end by a large mass of glass; this mass is again supported in the bowl, and by forcing in a strong blast of air, the workman causes the thick end to expand, when the whole presents the appearance of fig. 3, being a kind of short and wide bottle, with an enormously thick bottom; the sides being kept straight by the form of the hollow in the "block." The upper part of the bottle, or the "neck and shoulders" is called the "cap," and is of the same thickness as the whole sheet will be when finished. The "cap" being completed, the diameter of the bottle determines the future diameter of the cylinder.

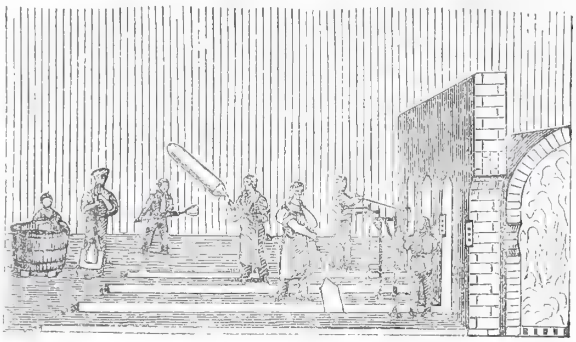
Fig. 3.

These preliminary portions of the manufacture are carried on at the side of an intensely heated furnace, called the "blowing furnace," having several circular openings of much greater diameter than the bottle before described, which being lifted out of the water, is inserted through one of the apertures into the heat, whilst the pipe is supported on a hook fastened for that purpose into the brickwork at the side; the bottle soon becomes exceedingly hot, and when almost melting is adroitly withdrawn and held down in a nearly vertical position by the workman, who stands on the edge of an opening like a saw-pit technically called a "grave," and allows the bottle to elongate by the weight of its thick bottom, occasionally forcing air down the pipe, and assisting the force of gravity by swinging or vibrating the pipe and glass to and fro, after the manner of the motion of a clock's pendulum.

A representation of this furnace is given in fig. 4, which shows the arrangement of the circular apertures and grooves, as well as the position the workmam occupies during this part of the process. The parallelism of the sides of the tube or "cylinder" is maintained by adjusting exactly the quantity of air blown into it; whilst the circular shape, straightness, and proper thickness of the sides and ends are secured by skilful management of the vibrations, and by a continued motion of the pipe on its axis, which from the time it is first plunged into the melted glass, until the cylinder is completed, is never stopped for an instant. Being thus made of about one-half the desired length, the half-formed cylinder resembles in shape a cylindrical high pressure boiler with hemispherical ends, attached at one end to the pipe, or it more closely resembles one of the bottles in which Maughan's Carrara Water is sold, the neck end of the bottle

answering to the "cap" end of the cylinder, and the bottom of the bottle to the end of the cylinder which is used when French shades are made, but is burst open in making German sheet. The cylinder is re-heated in the same furnace, but the bottom being too thin to elongate in a regular

Fig. 4.



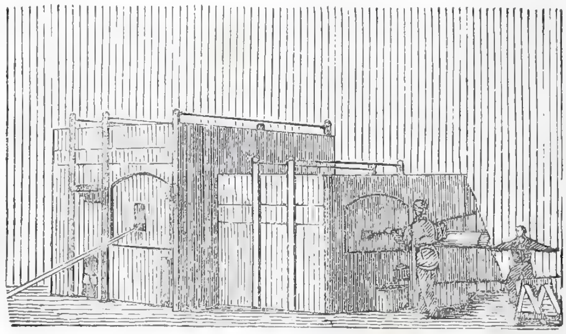
crane, and the closed end is held at a short distance from the fire; the extreme point thus becomes exceedingly hot and soft, so that by forcing air into the cylinder, the softened part expands, and becoming gradually thinner, at length bursts, leaving a hole of about two inches diameter; the cylinder being again heated for one-third its length, is withdrawn from the furnace and hung down, having at the same time a rapid rotatory motion on its axis communicated to it, which gradually expands the hole and at length renders the diameter of the cylinder equal throughout.

The blowing being completed, the cylinder is laid across a tressle, and is touched on the "neck" with a cold iron rod which effects what cold water failed in before, viz., the cracking of the glass; the short crack thus made is sufficient to cause the neck to separate at that spot, when a slight blow is given to the pipe, and the cylinder remains in this state until the man has finished his day's work, or as it is termed, until the end of the "journey." The "caps" are then cut-off by a process exactly the reverse of the preceding, for heat is applied to cold glass instead of cold to hot glass; the workman, by wrapping a cord or rod of red hot glass round the cylinder, causes the "cap" to crack off at the heated part, the process being sometimes hastened by touching the heated ring with cold water or a piece of cold iron.

The "blower" has now completed his portion of the work, and the cylinder is transferred to the splitter, who by holding it vertically in two V's, attached to an upright rod fast in a flat board, cuts the ends more true and square by means of a pair of spring pincers mounted on wheels, and having a glazier's diamond fastened to one of the jaws. The annexed sketch, fig. 5, shows more clearly how this is effected, the diamond describes a plane parallel to the board, so that the end is made perfectly square with the axis; the cylinder is next laid in a kind of cradle, and a straight rule being held inside by the workman parallel to the axis, he draws a diamond along the edge, which accordingly splits the cylinder from end to end; as his arm is not long enough to reach through, he inserts the diamond into a cleft stick, in nearly the same manner that painters set their brushes when wishing to paint sideways at a great height.

Fig. 5.

For the purpose of being opened or spread out flat, the split cylinder is passed to the "flattener," who completes the process at a reverberatory furnace or "kiln," consisting of two



chambers of unequal dimensions, with floors of stone or very large bricks made quite level and flat. The smaller of the chambers or the "spreading kiln" is heated to bright redness, and is separated from the larger and cooler chamber or "annealing kiln" by a brick partition, at the bottom of which, on a level with the floor, is a long slot about an inch high, forming the only communication between the kilns. At the red heat of the furnace the glass soon becomes flexible, and the "flattener" so regulates the heat that the glass may be easily bent, but is not melted nor even soft enough to stick together; the cylinder is now, as it were, unrolled, and being carefully spread open, all puckers and wrinkles are rubbed down by the "polissoir," which is a piece of wood of the same size and shape as a common brick, with a long iron rod serving as a handle struck at right angles into one side of it.